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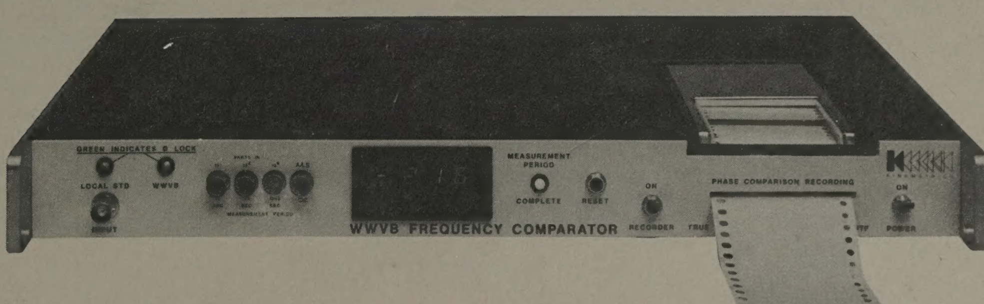
OPERATING AND SERVICE MANUAL

MODELS 60-TF, 60-TFD, 60-TFR, 60-TFC

WWVB RECEIVER FREQUENCY COMPARATOR



MODEL 60-TF

TRUE TIME INSTRUMENT CO., 3243 SANTA ROSA AVE., SANTA ROSA, CA 95401, PHONE (707) 528-1230

GLENN HARDEN

MANUAL DATED 7/82

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SECTION I

GENERAL INFORMATION

1-1 INTRODUCTION

1-2 This manual is designed and written to provide the owner of either the Model 60-TF, 60-TFD, 60-TFR or 60-TFC, with all the data and information to operate the unit and to fully utilize its many features.

1-3 The information included in this manual is as complete as possible and includes normal maintenance and adjustment data that may be required to facilitate field repair of the WWVB Receiver-Frequency Comparator.

1-4 This Frequency Comparator has been specifically designed to receive the 60 kHz carrier frequency from the National Bureau of Standards Radio Station WWVB and compare this standard frequency with that of a local oscillator. Comparisons from 1 part in 10^5 up to 1 part in 10^{12} can be made relatively easily with any of these units. Also available from these units is the standard time information as transmitted from WWVB. This time information is presented in a serial BCD, Modified IRIG H, TTL compatible form, suitable for drum or strip chart type recording.

1-5 This Receiver-Comparator is guaranteed to operate at any location within 1800 air miles of the transmitter at Fort Collins, Colorado. The Receiver-Comparator can be expected to operate at distances well beyond the 1800 mile mark if additional care is taken when setting up the antenna and when adverse noise conditions are not present.

1-6 In most cases the Receiver-Comparator will operate as received without any further adjustments. However, a gain control is provided to optimize the R.F. level reaching the Comparator and the level which reaches the code detector. In most locations it is best to operate the Comparator near full gain, except when the time code is desired, then it will be necessary to reduce the carrier level to well below saturation or the time code will not be detectable. The exact procedure for setting the gain control is covered more fully in Section 2-7.

60KHz TEST OUTPUT

SCOPE SET 1v/DIV 5ms/DIV
MEASURED AT FULL PEAK OF SIGNAL

PHASE LOCKED? WWVB	VOLTS, P-P	DATE	TIME
X	3.5	12-19-83	9:30 AM
✓	7	"	10:10 AM
✓	3	12-20-83	8:00 AM
✓	1	"	8:10 AM
X	.5	"	8:13 AM
✓	1.5	"	12:50 PM

1-7 WARRANTY

TRUE TIME INSTRUMENTS warrants each instrument it manufactures to be free from defects in its material and workmanship for a period of two years from the date of delivery. Under this warranty any instrument which is returned to us (freight pre-paid) and is found by us to be defective in material or workmanship, will be repaired or replaced (at our option) and returned at no charge to the customer.

Our obligation under this warranty is limited to the servicing or adjustment of any instrument returned. Items not covered by this warranty are: fuses, batteries and any illuminated parts or damage caused by accident or physical destruction of the instrument.

This warranty is expressly in lieu of all other obligations or liabilities on the part of TRUE TIME INSTRUMENTS. TRUE TIME INSTRUMENTS neither assumes, nor authorizes any other person to assume for it, any other liability in connection with its sales.

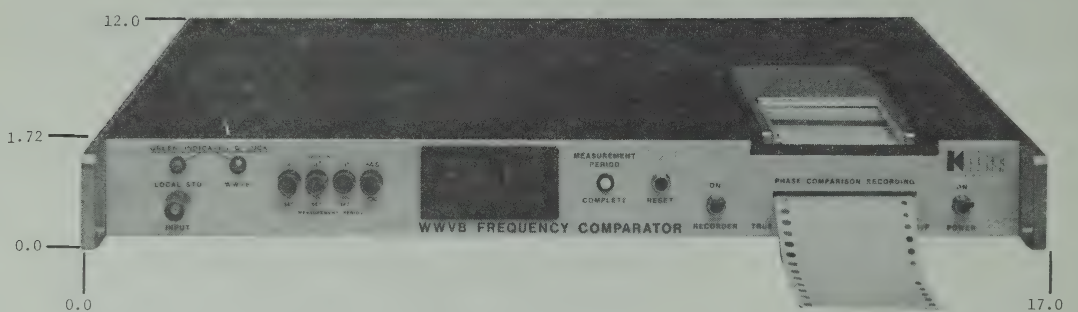
This warranty is applicable in the United States and Canada only. For other areas, consult "KINEMETRICS, INC."

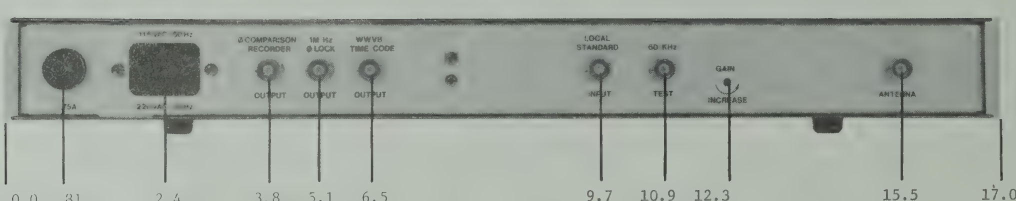
1-8 TECHNICAL SPECIFICATIONS

RECEIVER FREQUENCY:	60kHz
SENSITIVITY:	1μv into 50 ohms produces a stable recording on the strip chart recorder,
LOCAL STANDARD INPUT:	All harmonics of 20kHz to above 10 MHz. .5v to 10 v RMS into 1 KΩ in parallel with 50 pf.
OVERALL PHASE STABILITY:	$\pm$ μsec. from 0^{o} to 50^{o} C.
OPERATING TEMPERATURE RANGE:	0^{o} to 50^{o} C.
RECEIVER BANDWIDTH	$\pm$75 Hz @ 3DB points
RECEIVER DELAY (time code)	14 $\pm$ Msec.
OUTPUTS INCLUDE:	
DIGITAL READOUT: (Model 60-TF & 60-TFD)	3½ digits showing the signed phase error in microseconds between the local standard and the WWVB carrier. Selectable time base of 10,100, & 1000 seconds for quick readout in parts in 10, 10^{8} and 10^{9} respectively.
STRIP CHART RECORDING: (Model 60-TF & 60-TFR)	Complete recording of the phase difference of the local standard and the local standard and the 60 kHz carrier of WWVB. Recorder speed of 1"/Hour, 50 μsec. full scale. Accuracies to parts in 10^{11} can be obtained in one day.
AUXILIARY STRIP CHART:	
Rear Panel	-5V to +5V from 5K ohms
Front Panel (Model 60-TFD & 60-TFC)	0 to 1mA
PANEL METER: (Model 60-TFR & 60-TFC)	
Phase Comparison	0-50 μ seconds for full scale defelction
Signal Strength	Indicates relative signal strength
1 MHz PHASE LOCKED:	1 MHz phase locked to WWVB, TTL compatible square waves.

WWVB TIME CODE:	TTL compatible, Serial, BCD, Modified IRIG H form as transmitted from WWVB.
60 kHz WWVB CARRIER:	At approximately 50 mv to 1 v RMS dependent on setting of gain control.
POWER REQUIREMENTS:	115 VAC @ 60 cy. 15 watts.
SIZE:	17" wide x 1 3/4" high x 10 1/2" behind panel (43.2 x 4.4 x 26.7 cm). The Model 60-TF and 60-TFR mounts in standard 19" EIA systems with slides provided. Models 60-TFD and 60-TFC are provided with mounting brackets.

1-9 MODEL 60-TF DIMENSIONS





SECTION II

INSTALLATION

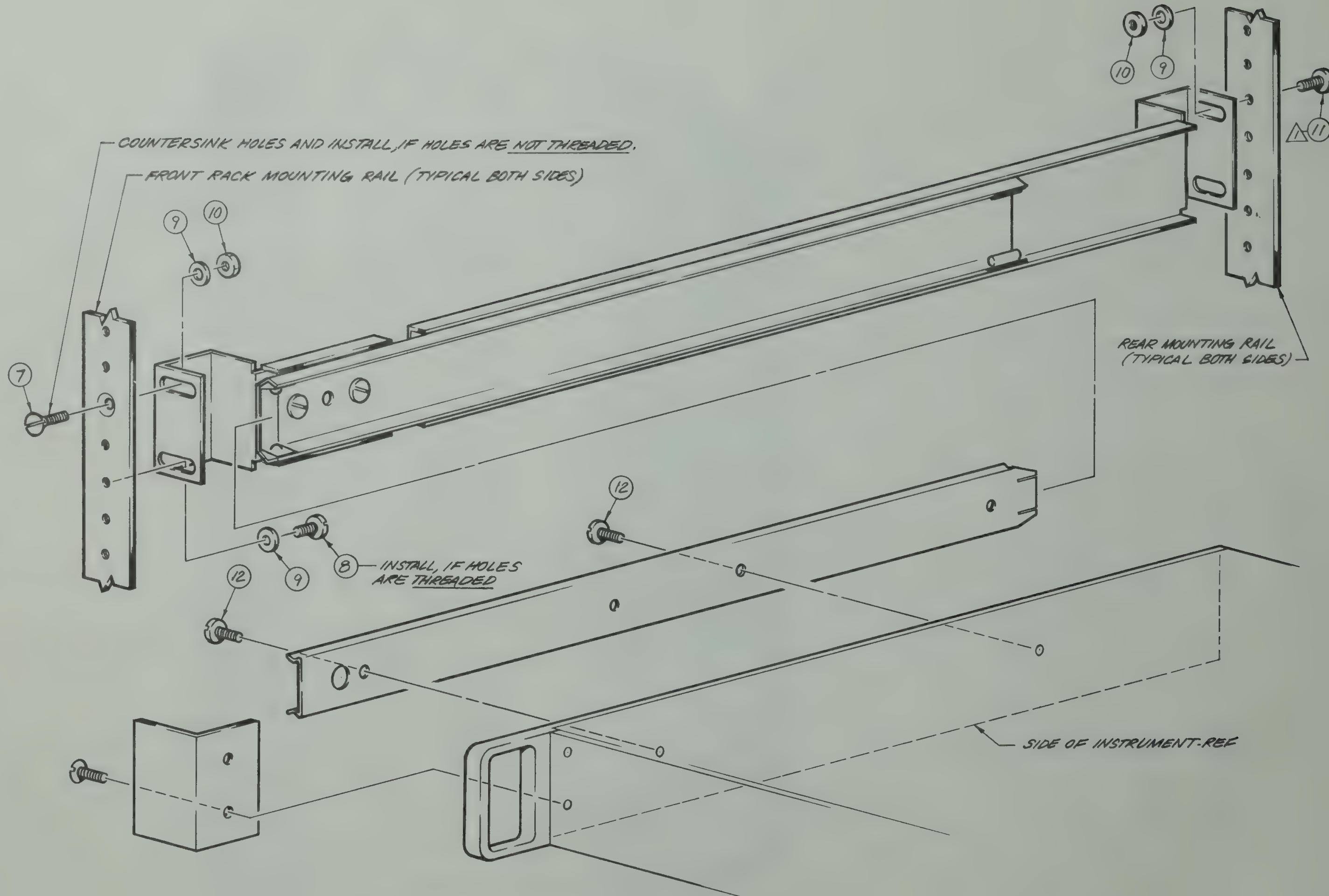
2-1 ANTENNA INSTALLATION

2-2 The Frequency Comparators are shipped ready for operation and will normally require no adjustment. The first step in set-up of the Comparator is to install the antenna. If a True Time antenna has been purchased with your unit, the installation instructions can be found in Section VII or VIII. The Comparator is shipped with one of two antennas. The installation instructions for Model A-60FS are found in Section VIII while Model A-60LW instructions are in Section VII.

2-3 RACK MOUNTING - MODEL 60-TF OR 60-TFR

2-4 If the Model 60-TF or 60-TFR Comparator is to be mounted in a 19" EIA system, all the hardware and slides are included for mounting. These units are mounted on chassis slides to allow access to the top of the unit to change the recorder paper supply as well as to allow viewing of the last two hours of recording. Figure 1 shows the typical installation procedure. The steps are outlined below:

1. Remove the inside sliding section of the chassis slide. This can be disengaged from the main part of the chassis slide by sliding it out as far as it normally slides and then grasping it firmly and pulling it further to free it from the slide carrier (portion with the ball bearings).
2. On the side of the Comparator remove the flat head screw that is farthest to the rear of the three in the triangular pattern.
3. Using the hole from which the screw was just removed and the hole further to the rear of the Comparator, mount the sliding section of the chassis slide to the Comparator. The sliding section should be mounted with the square cut end of the slide toward the fron panel (tapered end to the rear) and with the flat surface against the side of the Comparator. Two of the 8-32 x 3/8 pan head machine screws included, should be used on each side for this purpose. Discard the flat head screws (one on each side) which were removed.
4. Remove the two remaining flat head screws on the side of the Comparator and install the painted 1" angle with these screws. These ears cover the mounting rail when the unit is slid into position. Do the same on the other side of the unit with the second 1" angle.



TYPICAL BOTH SIDES

2. ALSO SOLD AS AN ACCESSORY KIT,
△ INSTALL IN BOTH PLAIN OR THREADED HOLES.

FIGURE 1 RACK MOUNTING OF COMPARATOR

5. The slide carrier (portion with the ball bearings in it) has been attached to the slide mounting brackets at the factory. The shorter of the two brackets is for mounting to the front rail of the rack system. If the front rail of the rack is not tapped for 10-32 screws, use an 82° countersink and countersink the front of the appropriate holes to a depth that will accept the flat head screws provided. Mount the front slide mounting bracket on the inside of the front vertical rail in the rack with the flat head screws and nuts as shown in Figure 1. If the rails of the system are tapped, use the 10-32 x 1/4 hex head cap screws from the rear to mount the bracket as shown in Figure 1.
6. Release the two screws that hold the rear slide mounting bracket to the slide. Move the rear mounting bracket back until the bracket contacts the rear vertical rail in the rack system. It may be necessary to remove the screws and reposition them to obtain the proper adjustment of the bracket.
7. Attach the rear mounting bracket to the rear rail as shown in the figure. Perform the same mounting operation on the other slide on the other side of the rack. Remove the rubber feet from the bottom cover, and replace the screws with the provided black flat head screws.
8. Slide the Comparator into the slides gently and feel for any binding. It may be necessary to release the screws which hold the mounting brackets to the vertical rails and readjust the position of the slides to obtain smooth sliding action.

2-5 RACK MOUNTING MODEL 60-TFD OR 60-TFC

2-6 When Rack Mounting the Model 60-TFD or 60-TFC in a standard 19" rack system, the user can use the rack mounting ears provided with the unit. These ears may be attached to the side of the cabinet by removing the two 8-32 flat head screws on one side of the instrument and placing the screws through the countersunk hole in the bracket and reinstalling the screw. The unit now may be mounted in a 1 3/4" opening in any EIA Standard 19" rack system.

2-7 R.F. LEVEL ADJUSTMENT

2-8 After the Comparator's physical installation is complete, connect the antenna coax (recommended lead-in is RG-58U) to the antenna connector on the rear of the unit. Connect the power cord to an appropriate A.C. source and turn on the power switch. The light indicating WWVB phase lock should now be red or green and the display should begin to show some digits on the 60-TF and 60-TFD.

2-9 If the unit is planned to be used only as a WWVB Receiver-Frequency Comparator, the gain control should be adjusted for full gain. If it is desirable to receive the WWVB time code, the level of the 60 kHz Output should be adjusted to about 150 mv RMS on the low code level.

2-10 The Comparator installation is now complete and the unit is ready for use. The operation of the Comparator is covered in the following section.

SECTION III

OPERATION

3-1 INTRODUCTION

3-2 The Model 60-TF family provides a means for accurate phase comparison between the 60 kHz WWVB transmissions of the United States National Bureau of Standards and a local frequency standard. The internal recorder on Model 60-TF and 60-TFR provides a permanent record of this phase comparison when accuracies of parts in 10^9 to 10^{12} are desired. For comparison accuracies of parts in 10^7, 10^8 or 10^9, a digital readout on Model 60-TF and 60-TFD is used since these relatively low accuracy figures can be obtained in a short period of time. For these same low accuracy level comparisons, the Model 60-TFR and 60-TFC use a front panel meter.

3-3 LOCAL STANDARD INPUT

3-4 Two input BNC connectors are provided for the input of the local standard. One is located on the front panel and the other is on the rear.

3-5 The local standard frequency can be any harmonic of 20 kHz to above 10 MHz. The level of the input frequency should be between .5V and 10V RMS. The waveform can be sinewave or squarewave.

3-6 LOCAL STANDARD AND WWVB PHASE LOCK LED

3-7 Two LED's are provided on the left side of the front panel to indicate lock or loss of lock with the transmitted signal from WWVB or the local standard.

3-8 After the local standard is connected to the proper BNC connector the LED above the words "Local Standard" should turn from red to green. If the LED remains red, the amplitude and waveform of the local standard should be checked to see if it is within the capabilities of the Comparator. If these two parameters are correct, the frequency of the local standard should be checked with an accurate counter. If the local standard is beyond 1 part in 10^5 from "on frequency", the Comparator will be unable to lock onto it. In this case the local standard should be adjusted to within the lock range of the Comparator.

3-9 After checking the above possible causes of lack of lock, if lock can still not be obtained, it is possible to self check the Comparator operation. With WWVB phase locked (as indicated by green LED), connect a cable from the "1 MHz Phase Locked" BNC connector on the rear of the unit to the "Local Input" BNC. If the Comparator is operating properly, the "Local Standard" LED should turn green indicating the Comparator is locking to itself. If the Comparator will

not lock to itself refer to the "Maintenance and Trouble Shooting" portion of this manual. After obtaining phase lock (green LED), if the local standard is removed from the input connector, the LED should immediately turn red.

3-10 When the antenna is installed and connected as described in Section 2-2 of this manual, the LED above "WWVB" should turn green. This indicates that the internal oscillator is phase locked to WWVB and the Comparator is ready to make phase comparisons. It may take up to one minute for the LED to turn green after connection of the antenna. This is due to the time constant on the lock circuit being fairly long. For the same reason when WWVB is disconnected, it may take one or two minutes to indicate loss of lock.

3-11 If the WWVB phase lock LED does not indicate lock, the installation of the antenna and reception of a good signal can be checked by viewing the 60 kHz as received on the BNC marked "60 kHz Test" on the rear panel of the Comparator. If no signal is present here, the problem is either antenna installation, the receiver has failed, or WWVB is temporarily off the air. If the signal is present at the test point and of adequate level (see Section 2-07) and does not show abnormal noise conditions overriding the transmissions, the problem may be drift of the 6 MHz crystal. This can occur with age as well as in cases where extreme temperatures are encountered. The procedure for readjusting the crystal for drift is covered in Section 5-12, "Maintenance and Trouble Shooting". If the LED continually flashes red-green when a good signal is being received, it is also an indication that the crystal may need readjustment for drift.

3-12 PHASE COMPARISONS

3-13 When the comparator is phase locked to both WWVB and the local standard as indicated by green LED's in both positions, the Receiver-Comparator is ready to perform phase comparisons.

3-14 DIGITAL READOUT (MODEL 60-TF AND 60-TFD)

3-15 Comparison accuracies to parts in 10^7, 10^8 or 10^9 can be obtained by using the digital readout on the front panel. To obtain a reading select the accuracy desired by pushing the corresponding button on the left side of the panel. The button marked "Parts in 10^7" will require a measurement period of 10 seconds; "Parts in 10^8", 100 seconds, while the button marked "Parts in 10^9" requires 1000 seconds. When using the readout, it is generally best to take the first reading on the 10^7 scale even if the local standard is normally to parts in 10^9. This 10 second investment will give a quick indication, if the accuracy is near this value and possibly save a 1000 second check if everything is not functioning as expected. A second factor that should be kept in mind when making comparisons using the digital readout, is that WWVB, for station identification purposes, advances its

carrier phase 45° at ten minutes after the hour and returns it at fifteen minutes after the hour. If a measurement period encompasses part of this phase shift, it should be considered when making the reading of the digital readout.

3-16 To start a reading, simply select the "Measurement Period" to give the accuracy desired and push the "Reset Button". This button will reset the readout to zero and begin the measurement period counter in the comparator.

3-17 When the LED marked "Measurement Period Complete" lights, a reading of the digital readout can be made. When the measurement period is complete, the readout is locked on its final reading until the reset button is pressed. The readout indicates the local oscillator frequency offset directly in parts in 10^7, 10^8 or 10^9 (as previously selected). The sign indicates the direction of the frequency difference. A plus sign indicates that the local is high with respect to the received carrier, while a minus sign indicates that the local is low in frequency.

3-18 In a case where the difference in frequency is beyond the capabilities of the readout (1999), the readout will count to 1999 and start over and count up again. This occurrence is indicated by a flashing display. The readout will lock on the overflowed number but continue to flash when the measurement period is complete. When a flashing readout is encountered, the next lower accuracy pushbutton should be selected and another measurement taken.

3-19 STRIP CHART RECORDER (MODEL 60-TF AND 60-TFR)

3-20 When it is desired to make comparison accuracies to a few parts in 10^9, 10^{10}, 10^{11} or to 5 parts in 10^{12}, the internal strip chart recorder must be utilized. This recorder plots the phase difference of a locally generated signal vs. that of the received carrier. The chart is set with a full scale of 50μs (25μs "0" center) phase difference. To adjust the center for zero, see Figure 2. This will only be needed after a period of time due to shock and other sources of vibration, as it is originally set at the factory. The recorder is of the sampling type, making a dot on pressure-sensitive paper once every 60 seconds. When standards of high precision are being calibrated and propagation conditions are stable, the trace resembles a continuous line.

FIGURE 2 ZERO ADJUSTMENT

3-21 The recorder chart paper installation is depicted in Figure 3 and described below. Chart paper can be ordered from True Time Instrument Co., in multiples of six rolls, by ordering part number 348-1. This same chart paper is available from Amprobe Instruments, 630 Merrick Rd., Lynbrook, NY 11563 by ordering part number 850D. It can also be obtained from many Amprobe distributors located throughout the U.S.

1. If the Comparator is mounted in a rack system, slide the unit far enough to expose the complete top of the recorder.
2. Set the slide switch on top of the recorder to "OFF".

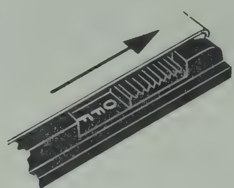


FIGURE 3A

3. Remove the top cover by placing index finger in center of front edge of cover and gently pull the cover forward and lift. The cover should now be loose and can be removed.

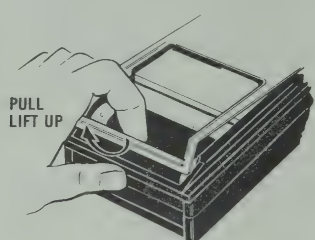


FIGURE 3B

4. Visually inspect the roll of paper to be installed. Rolled edge should be flat with no discontinuities.
5. Place the roll in the well at the rear of the recorder.
6. Unroll about 12 inches of chart paper.

7. With printed side up, insert the leading edge of paper under glass. If the leading edge is ragged, trim off a small strip at an angle.

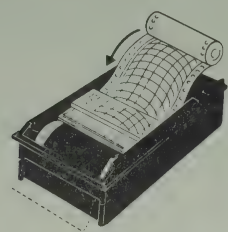


FIGURE 3C

8. Feed strip of paper across drive wheels and down into Comparator. It should come out through the slot provided in the front panel. If the paper does not come out slot, slightly fold up the leading edge to help it come into alignment with slot. If it still will not come through slot, insert a business card or something similar through the slot from the front panel side, and the paper will then easily come out through the panel.
9. Align chart time line, actual time of day, with True Arrow, if desired.

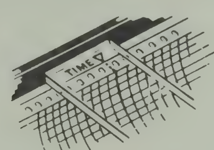


FIGURE 3D

10. Engage chart paper holes with paper drive sprockets.
11. Replace cover of recorder.
12. Turn the slide switch to the "ON" position.

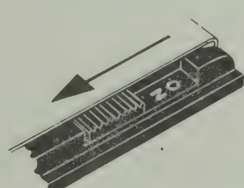


FIGURE 3E

3-22 To operate the recorder, be certain the slide switch on top of the unit is "ON" and turn "ON" the toggle switch located on the front panel. If desired, set the "Measurement Period" push button to infinite and push the reset button, thus centering the trace.

3-23 Figure 4 illustrates the recorder trace of a phase comparison made in October 1974 at True Time's plant in Santa Rosa, California. The chart width is 50 μs and is calibrated to 1 μs per small division, with zero center. The trace shows clearly the morning and evening diurnal shifts and the relatively unstable signal at night. Thus, the trace is most stable when the propagation path is in sunlight. These diurnal shifts result from variations in the height of the ionized D layer.

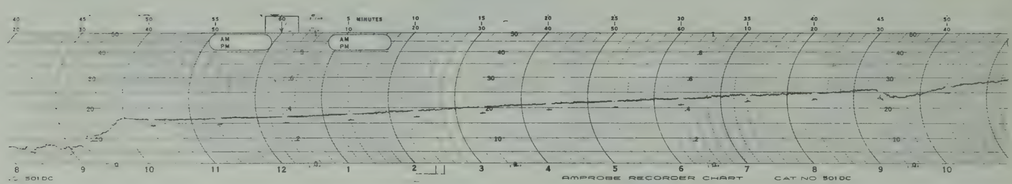


FIGURE 4 PHASE COMPARISON RECORDING

3-24 The slope of the trace plotted by the Comparator's strip chart recorder is, at a given instant, frequency offset between the local standard and the received signal $d\emptyset/dt$. The frequency difference can either be determined by the use of the chart in Figure 5 or by simple mathematical calculations.

3-25 To interpret the recorders trace by mathematical formula, it is necessary to select two points on the trace some distance apart. Read the phase difference in microseconds between two points

(the digital readout can be used for this if the pushbutton marked μs is selected and the recording is started by pushing the reset button) and note the time over this distance (number of hours or minutes) difference using:

$$E = \frac{\emptyset}{t} \qquad \text{where } E = \text{Frequency Difference}$$
$$\emptyset = \text{Measured Phase Difference (microseconds)}$$
$$t = \text{Time Elapsed During Measurement (microseconds)}$$

3-26 If "N" is the difference in μs of two readings three hours apart, then "N" can be said to be approximately the offset of the local oscillator in parts in 10^{10}, at about the midpoint of the three hour span. This is apparent from the following:

$$\frac{\text{N Microseconds}}{\text{3 hours}} = \frac{N}{(3600)\ 10^6} = \frac{N}{10^{10}}$$

3-27 Fractional time difference corresponds to fractional frequency differences:

$$\frac{\Delta t}{T} = \frac{\Delta f}{F}$$

3-28 For example, if the measured phase difference is 1.5 microseconds during an elapsed time of 3 hours:

$$E = \frac{1.5}{3(60)\ (60)\ (1 \times 10^6)}$$

$$E = 1.39 \times 10^{-10}$$

3-29 Figure 5 shows $E=\emptyset/t$ on a logarithmic scale for $\emptyset$ between .5 μs and 100 μs and t between 10 minutes and 100 hours. The fractional frequency difference (E) between the local standard and the received carrier of WWVB is the intersection of $\emptyset$ and t. The dotted line shows the same answer as in the example above.

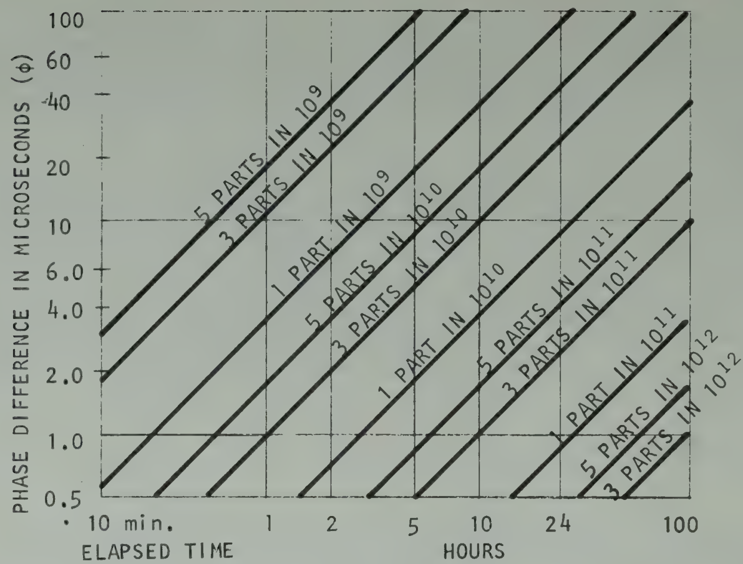


FIGURE 5 PHASE MEASUREMENT RESOLUTION

3-30 PANEL METER (MODEL 60-TFR AND 60-TFC)

3-31 The meter on the panel of these two models serves dual functions. When the switch below the meter is in the "Signal Strength" position, the meter provides the user with an indication of relative signal strength. Depending on the gain setting of the rear panel gain control, the user may see definite 1 second period drops in carrier level. This drop, once per second in level of the 60 kHz carrier by 10 db, is the time code encoded by NBS. For further information on the WWVB signal format, see Section IX .

3-32 By setting the switch, located under the meter, to the "Phase Comparison" position, the meter can be used to compare the phase of the local standard to NBS. Pressing the reset button centers the meter. The meter will then drift to the right or left depending on the direction of offset of the local standard. A drift to the right indicates the local standard is high, while a drift to the left indicates it is low in frequency.

3-33 As explained in Section 3-25 through 3-30, the accuracy in phase of the local standard is a function of microseconds' phase drift over time. A more "on frequency" oscillator will have a slower drift. The meter is set up for 50 μs phase drift for one full scale deflection (or after reset center to center). Therefore, an oscillator with good accuracy (1×10^9 or better) would require a very long time to indicate any phase drift. For this reason the meter should only be used below about 1×10^8 since the recorder on the 60-TFR provides good readout above that level. On the Model 60-TFC an external recorder should be used.

3-34 As an example, if the meter (after reset) drifted to the right pin, then went full left, and then returned to the center requiring 2 minutes to do this, the accuracy of the local standard would be (See Section)

$$E = \frac{+50 \text{ microseconds}}{2 \text{ min. } (60)\ (1 \times 10^6)}$$

$$E = +4.16 \times 10^{-7}$$

3-35 PHASE COMPARISON RECORDER BNC (MODEL 60-TFR AND 60-TFC)

3-36 This output BNC on the front panel of the Model 60-TFR and 60-TFC is provided to allow the user to connect the unit to an external recorder such as used in the Model 60-TF. The output from this connector is -1 to +1 ma for 50 microseconds or 40 microamps/microseconds.

3-37 PHASE MEASUREMENT ACCURACY

3-38 The phase measurement accuracy of the Comparator is primarily determined by the stability of the received WWVB signal at the receiving location. A measurement accuracy of 1 part in 10^{11} can usually be achieved during daylight transmissions. When a coherent measurement is carried out for several days, it is possible to approach 5 parts in 10^{12}, the accuracy of the signal as transmitted by the National Bureau of Standards.

3-39 Ionosphere phase anomolies are sufficiently unlike the nature of a quartz (or atomic) standards aging characteristics as to be distinguishable. Occasionally, daytime ionosphere activity does occur (mostly in the winter months) and should be considered for proper evaluation of the data records.

3-40 Achieving maximum usable comparison precision of the WWVB signal can be accomplished by giving greater weight to phase records made during days having constant signal level. If daylight fading occurs, it is a certain indication that ionosphere disturbances are taking place and these are likely to be accompanied by apparent received phase instability. The maximum error attributable to ionosphere disturbances which will normally be encountered are about 1 part to 10^9. Another helpful method of determining accuracy depends upon a fairly good knowledge of the behavior of one's own local standard. Once the aging rate has been determined, it can be removed from phase records with reasonable accuracy.

SECTION IV

THEORY OF OPERATION

4-1 BLOCK DIAGRAM

4-2 Overall operation of the WWVB Receiver-Frequency Comparator can best be understood by examination of the basic block diagram as shown in Figure 6. The brief description of the function of each major block is followed by a more in-depth description of the assemblies. Complete schematics for reference to specific components can be found in Section VI, "Schematics and Parts Lists".

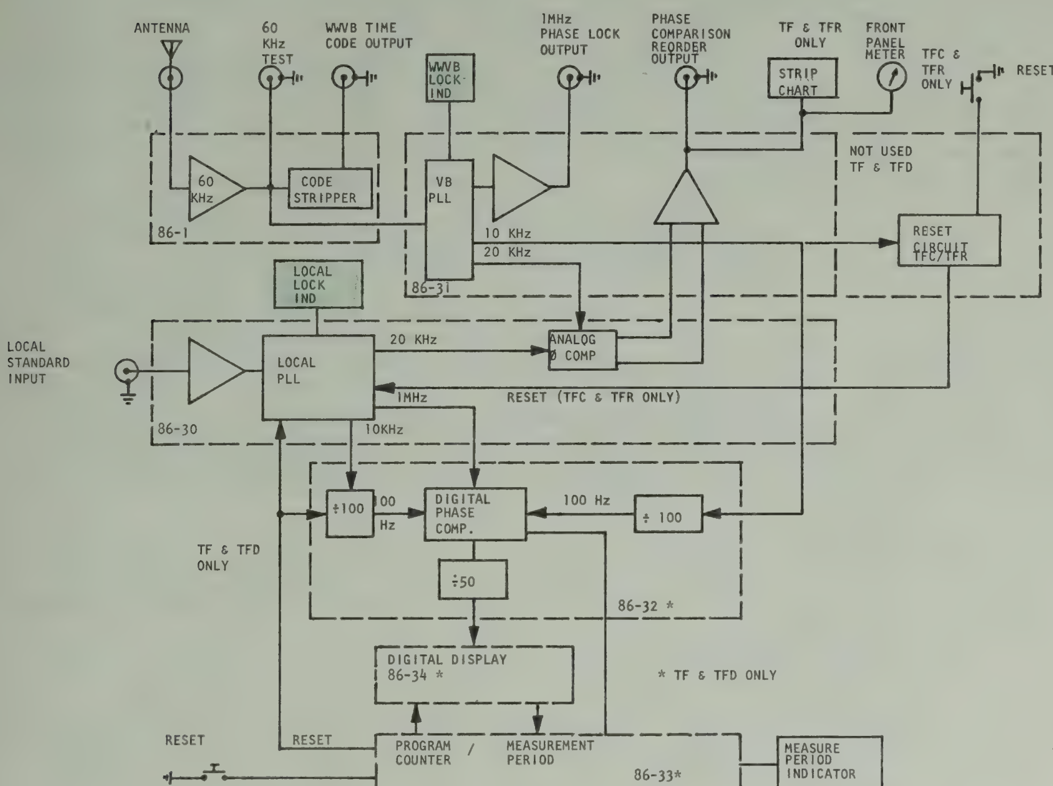


FIGURE 6 BLOCK DIAGRAM MODEL 60-TF SERIES

4-3 The incoming signal from WWVB is first amplified to a level between 150 and 700mx RMS. It is then fed into the WWVB phase locked loop which acts as a tracking filter with a noise bandwidth of approximately .5 Hz. The VCO in this PLL runs at 6 MHz, a division by 6 yields a 1 MHz output which is phase locked to WWVB. Division by 100 provides 60 kHz for phase comparison with WWVB, and additional division provides 20 kHz, 100 Hz, 0.1 Hz, 0.01 Hz, and 0.001 Hz for use elsewhere in the instrument.

4-4 The local standard to be compared to WWVB also passes through a PLL, allowing the use of many frequencies and signal levels. The loop can lock onto harmonics of 20 kHz to above 10 MHz. Another divider chain provides the required frequencies for use in the instrument. This divider chain can be reset to set the phase of the local signal to within 1 μs of the WWVB reference phase.

4-5 The 20 kHz signals from the two PLL's drive the analog phase detector to provide a full scale range of ±25 μs.

4-6 Assembly 86-32, the Digital Phase Comparator operates at 100 Hz and each cycle, it generates a burst of 1 MHz pulses equal in number to the phase difference in microseconds. Each reading consists of the sum of 50 of these bursts (0.5 seconds worth), so a divide by 50 scales the count properly.

4-7 The display consists of a CMOS LSI chip which contains a 3½ digit counter, latches and multiplex circuitry.

4-8 All of the operations of the Digital Phase Comparator and the Display boards are controlled by the Program Counter board, Assembly 86-33. This board generates the basic 1 Hz from the WWVB signal and distributes the timing commands appropriately to the rest of the instrument. The Models 60-TFR and 60-TFC do not include the digital display, consequently, Assemblies 86-32, 86-33 and 85-34 are not used in these models. An alternative <u>Reset</u> circuit is used which is located on the 86-31 Assembly.

4-9 <u>WWVB RECEIVER - ASSEMBLY 86-1</u>

4-10 The WWVB Receiver consists of the following sections as shown in the block diagram below.

1. 60 kHz Tune Amplifier
2. Variable Gain Stage
3. Detector
4. Spike Suppressor
5. Low Pass Filter
6. Comparator

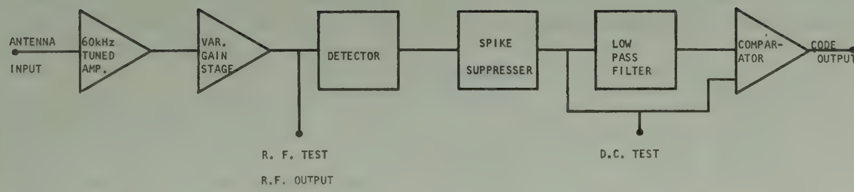


FIGURE 7 BLOCK DIAGRAM - WWVB RECEIVER

4-11 <u>60 KHZ TUNED AMPLIFIER</u> - The tuned amplifier consists of OA1, OA2, and OA3, together with tuned circuits T1 C2, T2 C3 R4, and T3 C5 R7. The gain of the amplifiers is stabilized at about 5 per stage by feedback resistor pairs R2 and R3; R5 and R6; R8 and R9; and also by the voltage dividers comprised of R4 and T2 C3 and R7 and C4 T3.

4-12 The input transformer has a turns ratio of 1:100 so the overall gain of the R.F. amplifier is about 1.2×10^4.

4-13 <u>VARIABLE GAIN STAGE</u> - The variable gain stage consists of OA4 together with R10, R11 and R12 and provides a gain of about 0.5 to 15.

4-14 <u>DETECTOR</u> - The detector consists of OA5 with R13, R14, D1 and D2. It is a "Precision" rectifier which reduces the effective diode conduction threshold voltage of about 0.6 V by the open loop gain of the operational amplifier (about 20 at this frequency) to provide a detection threshold of about 15 mv RMS.

4-15 <u>SPIKE SUPPRESSOR</u> - The spike suppressor consists of OA6 with R15, R16, R17 and C8. This provides a single pole low pass filter with a time constant of 20 ms to reduce erroneous detection of noise spikes as a high carrier level (a "0" in the time code).

4-16 <u>LOW PASS FILTER</u> - The low pass filter consists of OA7 with R18 through R21, C9 and C10. It provides a two-pole pass with a time constant of about 30 seconds. The purpose is to provide an average carrier level for comparison with the instantaeous level. This makes the digitizing comparison independent of the average signal strength.

4-17 <u>COMPARATOR</u> - The comparator is made up of OA 8 with D3.

D3 clamps the output at 0.6 volts below the average carrier level and 4.7 volts above this level. This results in a "0" level between -0.6 and +0.6 volts and a "1" level between 4.1 and 5.3 volts depending on the signal strength.

4-18 LOCAL INPUT BOARD - ASSEMBLY 86-30

4-19 The local input board consists of the following main segments:
1. Local Phase Lock Loop
2. Local Phase Lock Detector and Indicator Drivers
3. Analog Phase Detector
4. Part of the Local Divider Chain

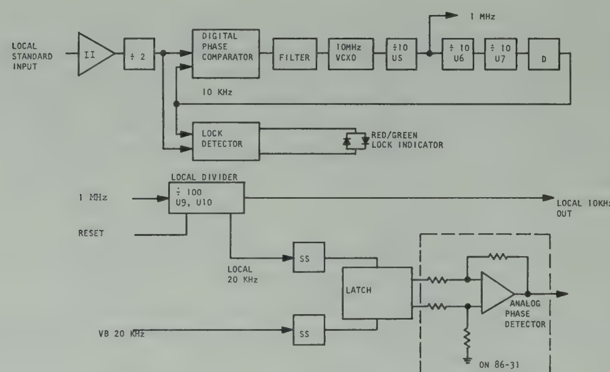


FIGURE 8 BLOCK DIAGRAM - LOCAL INPUT BOARD

4-20 LOCAL PHASE LOCK LOOP - The local phase lock loop phase locks a 10 MHz oscillator to the local standard which is connected to the Comparator. The loop consists of U2 the digital phase comparator, U3 the differential to single ended converter and low pass filter. Also the voltage-controlled crystal oscillator Q1 and Q2, and U5-U7 a divide by 1000 counter.

4-21 The phase comparator is a "D" flip flop which receives a "squared" version of the local standard from U1. The first section of U2 divides the local standard by 2 and provides a 50% duty cycle signal to the second half of U2. A 10 kHz signal from the VCXO is delayed approximately 50 nanoseconds by one half of U8. This 10 kHz signal is the clock for the phase detector. At phase lock the output of the phase detector is a square wave of approximately 50% duty cycle.

4-22 One section of U3 amplifies the output of the phase detector and shifts the level so that it is centered around ground. The next section of U3 provides filtering and controls the dynamic characteristics of the PLL.

4-23 Q1, Y1 and CR3 make up the VCXO, a Colpitts circuit with the crystal load capacitance made up largely by the varicap. The control range is about ± 20 ppm. U5-U7 divide 10 MHz oscillator output down to 1 MHz and 10 kHz.

4-24 The phase lock detector is another "D" flip flop, the second half of U8. This flip flop switches pin 8 low when there is a positive transition of pin 11 during the 100 n section period centered around the 10 kHz clock to the phase detector. This negative transaction sets the latch, composed of two sections of U4. Pin 6 of U8 resets this latch each 10 kHz period. The section of U3 connected to this latch turns Q3 off whenever the average value of the output signal from U4 is greater than approximately 4.0 volts. Q3 and Q4 energize the Local Lock indicator.

4-25 <u>ANALOG PHASE DETECTOR</u> - U11 and U12 are the analog phase detectors. The 20 kHz signals shown are square waves and initially in phase. U11 produces short negative pulses on the falling edge of the WWVB 20 kHz and on the rising edge of the local 20 kHz. These pulses alternately set and reset the latch U12 yielding a 50% duty cycle as long as the two signals remain in phase.

4-26 Since the CMOS gate outputs swing essentially between ground and Vcc, the average voltage at each output is ½ Vcc and their difference is zero. When the two signals drift in phase, the duty cycle changes and thus the average output voltage.

4-27 <u>LOCAL DIVIDER CHAIN</u> - The local divider chain U9 and U10 further divides the local standard locked 10 MHz for use elsewhere in the Comparator. Their contents are reset to zero at the beginning of a measurement period. This insures that initially the phase difference between the local chain and the WWVB chain is zero.

4-28 <u>WWVB INPUT BOARD - ASSEMBLY 86-31</u>

4-29 As shown in the block diagram on the next page, the WWVB input board consists of:

1. WWVB Phase Lock Loop
2. Part of the WWVB Divider Chain
3. WWVB Lock indicator Driver
4. The Analog Phase Output Amplifier

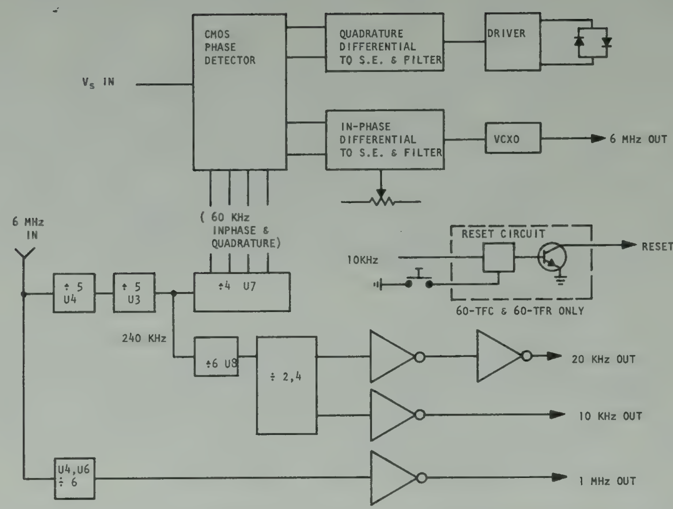


FIGURE 9 BLOCK DIAGRAM - WWVB INPUT BOARD

4-30 WWVB PHASE LOCK LOOP - The WWVB phase lock loop consists of U1, U2, U3, Q3, Q4, Y1 and C9.

4-31 U1 is a phase comparator which compares the incoming WWVB signal with the outboard 60 kHz signal. U2 converts the balanced output of the phase comparator to single ended form. U3 is a low pass filter which determines the dynamic characteristics of the loops.

4-32 Q3, Q4, Y1 and C9 make up the 6 MHz voltage controlled crystal oscillator; it has a control range of approximately ±5 PPM.

4-33 U4, U7 and U8 divide the 6 MHz down to 60 kHz needed for the phase comparator.

4-34 WWVB DIVIDER CHAIN - U4 and U6 divide the frequency of the phase locked 6 MHz by 6 to provide a 1 MHz signal which is phase locked to WWVB. The phase of the signal may wander ± a few hundred nanoseconds over a few seconds due to the received noise energy in the .5 Hz noise bandwidth of the phase lock loop. Some phase variation at a 1 Hz rate is also present associated with the time code modulation.

4-35 U4, U8 and U9 divide the WWVB phase locked frequency to provide a 20 kHz output for the analog phase comparator and a 10 kHz output for the digital portion of the instrument.

4-36 WWVB LOCK INDICATOR DRIVER - Q1 and Q2 drive current through the WWVB lock indicator in the appropriate direction to indicate phase lock or its loss, based on the level of the output of the WWVB phase lock detector. Q1 is off and Q2 is on in a phase lock condition, and the reverse when lock is lost.

4-37 ANALOG PHASE OUTPUT AMPLIFIER - U2 provides buffering and low pass filtering for the output of the analog comparator. The scale factor is +5 usec./volt. The output voltage becomes more positive as the local standard phase advances with respect to WWVB.

4-38 DIGITAL PHASE COMPARATOR - ASSEMBLY 86-32 (USED ON 60-TF AND 60-TFD)

4-39 The digital phase comparator board consists of:
1. Portion of the Local Divider Chain
2. Part of the WWVB Divider Chain
3. Digital Phase Comparator
4. Digital Phase Comparator Divider Chain
5. Polarity Detector
6. Overflow Counter
7. Overflow Latch

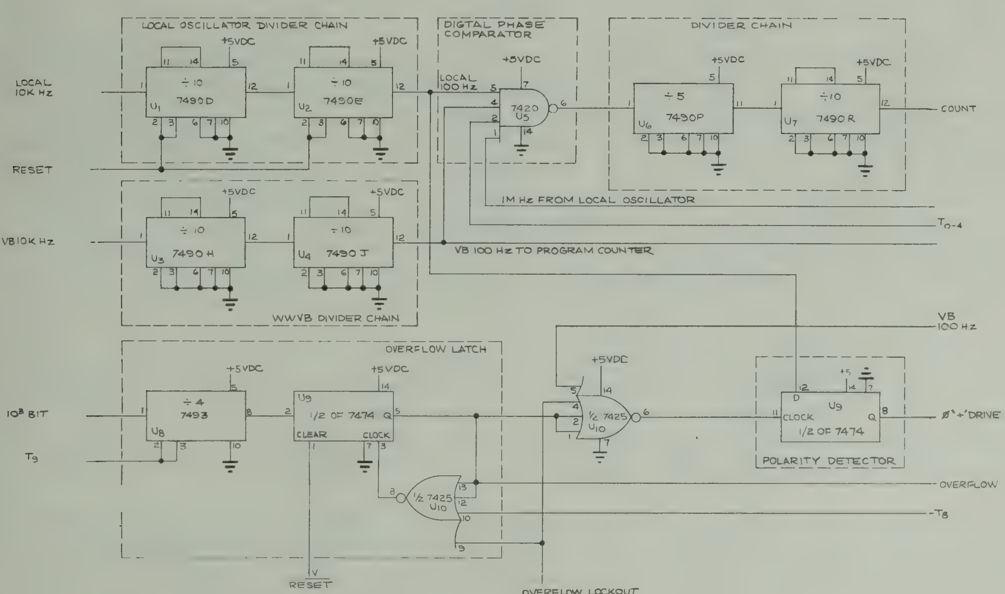


FIGURE 10 BLOCK DIAGRAM - DIGITAL PHASE COMPARATOR

4-40 PORTION OF THE LOCAL DIVIDER CHAIN - U1 and U2 comprise a divide by 100 portion of the local divider chain. Their contents are preset to "zero" at the beginning of a measurement, this insures that initially the phase difference between the local chain and the WWVB chain is zero.

4-41 PART OF THE WWVB DIVIDER CHAIN - U3 and U4 comprise a divide by 100 portion of the WWVB divider chain.

4-42 DIGITAL PHASE COMPARATOR - The digital phase comparator is a 4 input nand gate. 2 inputs are 100 Hz square waves whose phase difference is to be measured. One input is a 1 MHz clock to provide 1 μ second resolution and one input is an enable input. Operation may be clarified by reference to Figure 11 below.

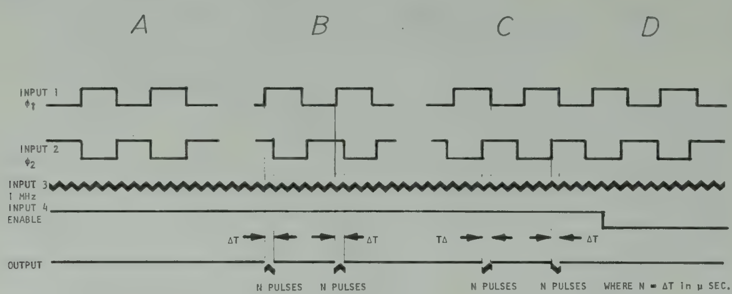


FIGURE 11

4-43 Initially at "A" inputs 1 and 2 are exactly 180° out of phase; since one or the other is always low, the output of the gate is always high and no output transition occurs. At "B" input 2 lags input 1 by ΔT and the clock pulses pass through the gate for the duration of the overlap of the high states of 1 and 2. Similarly at "C" when 2 leads 1 by ΔT the clock pulses pass through the gate for ΔT each cycle. Since the clock rate is 1 MHz, the number of pulses passing the gate is equal to the phase difference in micro seconds, independent of whether 1 leads or lags 2. At "D" a low level on the enable line inhibits any output.

4-44 DIGITAL PHASE COMPARATOR DIVIDER CHAIN - The output of the digital phase comparator goes to a divide by 50 (U6 and U7) before being sent to the display counter. This reduces the count rate to a value well within the capability of the 74C928, and scales the count properly for display since 50 pulse bursts are accumulated.

4-45 POLARITY DETECTOR - Since the phase comparison ignores the sense of the phase difference it is necessary to use a secondary polarity detector to sense which phase leads. A "D" type flip flop does this task. The state of the local 100 Hz is examined at each positive transition of the WWVB 100 Hz. When an overflow occurs, or at the end of a preselected measurement period, the polarity is frozen in its current state until the system is reset with the reset button.

4-46 OVERFLOW COUNTER - If the phase difference between the local standard and the WWVB signal exceeds the 2 msec. capacity of the display, it is necessary to indicate this condition. U8 the overflow counter increments on each negative transition of the 8 x 10^2 bit of the display counter. IE: at each multiple of 1000 after two counts an overflow has occured, and Q goes high. The overflow counter is reset by the overflow counter reset gate.

4-47 OVERFLOW LATCH - One half of U9 is the overflow latch. It looks at the output of the overflow counter and latches the overlow condition at T8 after an overflow occurs. It stays latched until cleared by the reset signal from the reset button.

4-48 PROGRAM COUNTER - ASSEMBLY 86-33 (USED IN 60-TF AND 60-TFD ONLY

4-49 The program counter board consists of:
1. Program Counter
2. Measurement Period Divider Chain
3. Reset Flip Flop
4. Measurement Period Flip Flop
5. Blanking Gate
6. Transfer Gate
7. Overflow Reset Gate
8. Start Gate

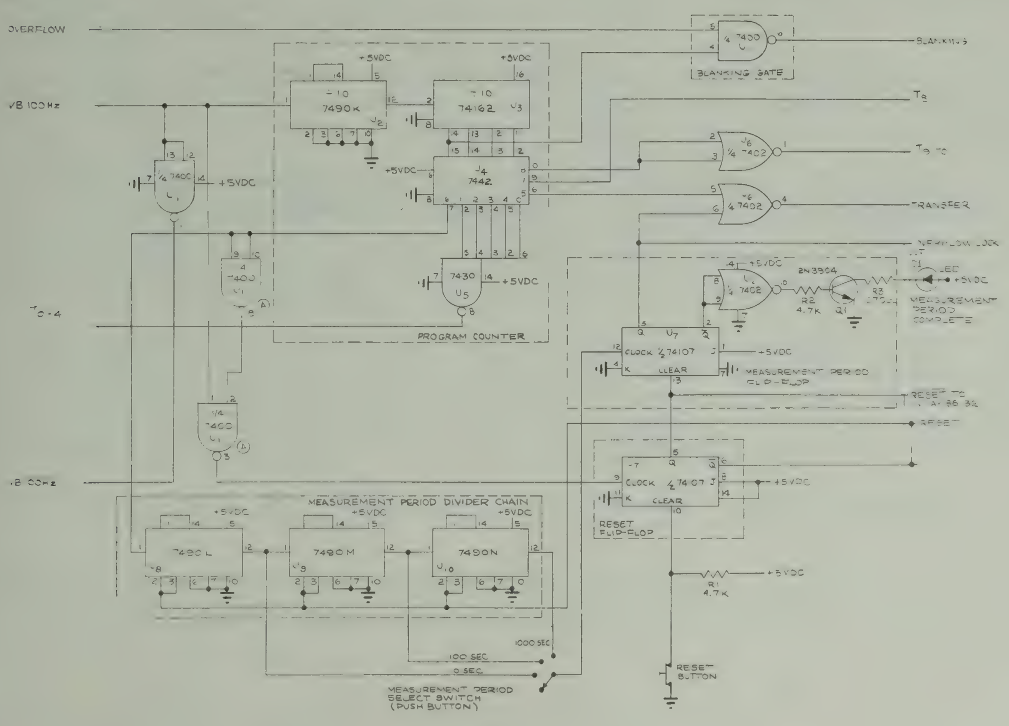


FIGURE 12 BLOCK DIAGRAM - PROGRAM COUNTER

4-50 PROGRAM COUNTER - The program counter further divides the 100 Hz from the WWVB signal to provide the control timing to coordinate the activities of the entire instrument. U2 and U3 divide the 100 Hz down to 1 Hz, U4 decodes the BCD output of U3 into 1 of 10 line format. Each one of the ten output lines goes high for 100 msec. out of each 1 second cycle. These lines are used to control all the other logic in the instrument. Figure 13 shows the overall timing diagram.

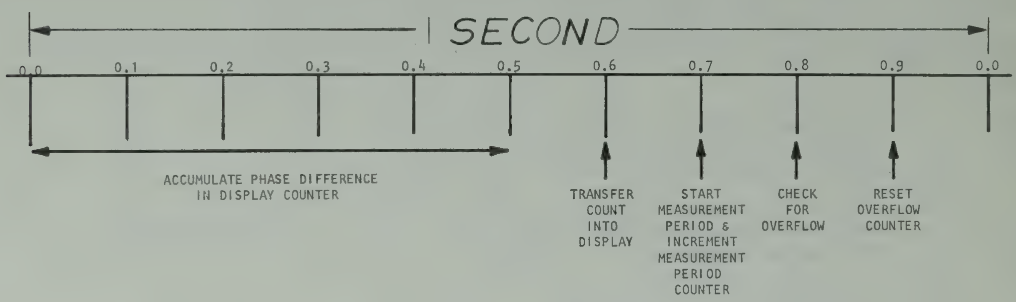


FIGURE 13 TIMING DIAGRAM

4-51 MEASUREMENT PERIOD DIVIDER CHAIN - The measurement period divider chain offers a selectable ÷ 10, ÷ 100 or ÷ 1000 to provide the time base for the three fixed measurement intervals.

4-52 RESET FLIP FLOP - The reset flip flop provides synchronization between the reset button and the WWVB synchronous time base in the instrument. It is forced to the reset state by the button and subsequently toggled back to the run state by the first positive transition of the WWVB line during the next start interval T7.

4-53 MEASUREMENT PERIOD FLIP FLOP - This controls the transfer of information into the display allowing update of the display each second during the measurement period. It is set by the reset condition and cleared by the negative transition of selected output of the measurement period divider chain.

4-54 BLANKING GATE - The blanking gate blinks the display after an overflow is detected.

4-55 TRANSFER GATE - This gate allows the transfer of the contents of the display counter into the display latches during the Measurement Period.

4-56 OVERFLOW RESET GATE - The overflow detector reset gate resets the overflow detector counter each cycle. Without this, the accumulated counts in it might cause a false overflow indication.

4-57 START GATE - The start gate provides synchronous start at the first positive transition of the WWVB 100 Hz during the first T7 after the release of the reset button. See the previously mentioned timing diagram.

4-58 DIGITAL DISPLAY BOARD - ASSEMBLY 86-34 (USED IN 60-TF AND 60-TFD ONLY)

4-59 The digital display board consists of:

1. Counter, Latch and Multiplex
2. Decoder, Segment Driver, Digit Drivers
3. Display

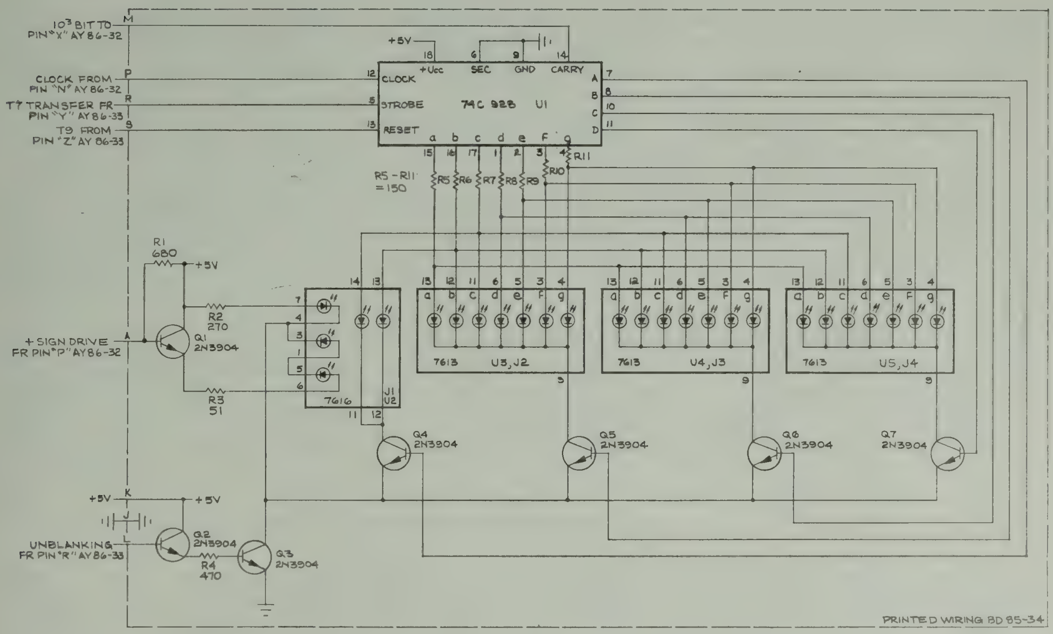


FIGURE 14 BLOCK DIAGRAM - DIGITAL DISPLAY BOARD

4-60 <u>COUNTER, LATCH AND MULTIPLEX</u> - The counter, latch and multiplexer is a 74C928 which is an LSI chip containing a 3½ digit counter, latches and miltiplexing circuitry. The counter increments on positive going transitions at the count input. The contents of the counter are transferred into the latches while the transfer input is high and the counter is reset to zero by a positive level on the reset line. The contents of the latches are multiplexed out on the BCD and digit lines by positive transitions of the MUX input. In addition the most significant bit is brought out and used for overflow direction.

4-61 <u>DECODER-SEGMENT DRIVER, DIGIT DRIVERS</u> - Digit and segment drivers decode the BCD outputs and provide sufficient current capability to drive the display.

4-62 <u>DISPLAY</u> - The display consists of three seven-segment LED displays and a ½ digit display giving a capacity of ± 1999 μsec.

SECTION V

MAINTENANCE AND TROUBLE SHOOTING

5-1 MAINTENANCE

5-2 The Model 60-TF Receiver -Frequency Comparator has been designed and constructed such that it will need little or no maintenance once it is installed and operating. There are only four areas which can be adjusted in the unit. One is the gain control on the rear of the unit, second is the tuning of the "TFR" WWVB receiver, third, the local standard voltage controlled oscillator, and fourth, the WWVB voltage controlled oscillator trimmer.

5-3 WWVB RECEIVER GAIN CONTROL - ASSEMBLY 86-1

5-4 As described in Section 2-7, the gain control should be adjusted for a level at the 60 kHz output point of .7 volts RMS if the unit is to be used as a frequency comparator only and to about .15 volts RMS if it is desired to utilize the Time Code as transmitted by WWVB (described in Section IX).

5-5 In the case where the unit is to be used strictly as a comparator the intent is to adjust the gain control to a point at which the amplified 60 kHz from the received signal is just short of saturating the receiver. This level must be set at each receiving location since the signal strength varies with location. The setting should be at the time of day when the signal is the strongest at the receiving location. This is normally when the sun is midway between the transmitter at Fort Collins, Colorado and the receiving location. The saturation level is at about 1.0 volts and, therefore, it is usually safe to set the gain control for about .7 volts maximum.

5-6 When it is desired to utilize the time code transmitted by WWVB, it is necessary to set the level of the 60 kHz lower. The reason for this is that the "O" and "L" levels of the output are offset from "O" volts and "5" volts by the average of the signal level. By keeping the signal level average low, this offset is negligible.

5-7 WWVB RECEIVER TUNING - ASSEMBLY 86-1

5-8 The assembly 86-1 has been designed with only one type of active device to facilitate repair. Normally no adjustment should be required after the receiver has been tuned before leaving the factory. The R.F. alignment procedure is included below in the event that it is necessary at some date.

12-14-83

USING
HP 3330B + 355CD
TUNED TO 60kHz

ADJ TUNING

5-9 The test equipment needed is:
- Signal generator, adjustable to 60 kHz with output adjustable from 1.0 μv to 100 μv
- AC voltmeter

5-10 Set the gain control of the receiver to maximum (counter clockwise) and set the signal generator to 60 kHz. Connect the generator to pins "B" and "C" on the printed wiring board. Adjust the output of the generator (approximately 4 uv) until 1.0 VDC is obtained at pin "E" on the receiver board. Reduce the gain control on the receiver until the voltmeter reads .5 volts. Tune the core of T1 for maximum output of the receiver, reducing the output of the generator to maintain the .5 volts at pin "E". Adjust the cores on T2 and T3 using the same procedure, thus having all three coils tuned for resonance at 60 kHz.

5-11 <u>WWVB VOLTAGE CONTROLLED OSCILLATOR</u> - ASSEMBLY 86-31

5-12 After a few years of operation, the 6 MHz crystal in the WWVB PLL may have aged enough to necessitate adjustment of the center frequency of the voltage controlled crystal oscillator. This situation can be recognized by the presence (during a WWVB locked condition) of more than ±7 volts at pin 6 of U3. This condition will occur very gradually over a period of months and will first be observed as a fairly regular red-green flashing of the WWVB lock LED (with the time code). This condition can be distinguished from a weak signal due to propagation conditions, transmitter failures or antenna malfunctions by viewing the 60 kHz output with an oscilloscope.

5-13 The oscillator center freqency is adjusted by the ceramic trimmer located on circuit assembly 86-31. Refer to Section VI "Schematic and Parts List" to help in identification of the assembly and the trimmer. To open the Comparator, remove the five phillips head screws in the top cover and lift off the lid. Care should be taken since the 60-TF and 60-TFR recorder is mounted in the lid and a cable connects it to the instrument. This cable is long enough to permit the recorder and the lid to be set on a bench next to the unit.

5-14 Two methods are recommended for adjusting the trimmer and both are listed here. When adjusting the trimmer it must be kept in mind that the temperature of the crystal in the closed case runs about 15° C above the ambient and since the case must be opened to adjust the trimmer, it is best made at an ambient temperature about 15° higher than normal operation. It is worth mentioning that the frequency versus temperature characteristics of the oscillator are generally quite nonlinear, roughly a parabolic form. One extreme in frequency occurs near the middle of the temperature range and the other extreme at both ends.

WITH 60.000KHz @ -100dBm

INPUT HP 3330B

WHILE LOCK LOSS WHEN RANGE

PHASE GAIN IS REDUCED TO GIVE

540mV P-P OUT @ 60KHz TEST OUT

WITH GAIN TURNED MAX UP, LOCK

IS LOST @ -105dBm (~0.5µV)

TEST OUT IS 150mV P-P

IN	60KHz TEST OUT
-100dBm	800mV P-P
-80dBm	8V P-P
-60dBm	25V P-P

WITH -100dBm INPUT   -90dBm

LOSES LOCK AT: 60.000.3 KHz

60.000.5

59.999.3

5-15 The first method requires a counter of accuracy known to be within ±1 PPM. Connect the counter to the "1 MHz Phase Locked Output" on the rear of the comparator, ground pin 6 of U3 (a 3140) TP2 RIGHT BOARD and adjust the trimmer for exactly 1 MHz at the output. Refer to Section VI to aid in identification of U3 and the trimmer if needed.

5-16 The second method does not require a counter, but does require more care. (Unit Receiving WWVB) With an oscilloscope or voltmeter measure the voltage at pin 6 of U3 and adjust the trimmer for zero volts average at this point. Since the control range of the trimmer is several times that of the varicap in the oscillator, it is easy to overadjust the loose lock. If lock is lost, it can be regained by carefully adjusting the trimmer a very small amount at a time and waiting to see if lock is regained at that setting. If not, another fine adjustment can be made and again wait; ultimately, zero average volts will be found.

5-17 <u>LOCAL STANDARD VOLTAGE CONTROLLED OSCILLATOR</u> - ASSEMBLY 86-30

5-18 The local voltage controlled oscillator, because of its large control range as compared to drift, is not likely to ever need adjustment. However, if desired, it can be adjusted by connecting a local standard known to be within ±1 PPM accuracy and adjusting the trimmer on assembly 86-30 for zero average volts at pin 8 of U3 (a TL084). If the comparator is phase locked to WWVB, the MHz output on the rear of the instrument can be used as the local standard for this adjustment.

5-19 <u>TROUBLE SHOOTING</u>

5-20 Every effort has been made by the factory to assure that failures will not occur. Due to the inherent reliability of the solid state components and the factory test and burn-in procudure, it is very unlikely that a failure will occur for many years. Due to the complexity of the circuitry in the unit, it is recommended that in case of failure, the Receiver-Comparator be returned to the factory for repair and adjustment. If a failure occurs which the user feels he can repair, if it is not possible to return the unit, a brief coverage of areas where problems may occur and troubleshooting tips are included below. These tips along with the schematics in Section VI, as well as the Theory of Operation in Section IV, should help the user in locating problems which might occur.

5-21 In any case of failure, one probable cause may be a broken wire in the wiring harness. Due to vibration and the shock of moving the unit, it is possible that a wire may break at the point of termination. To begin looking for this possible cause, analyze the observed symptoms and refer to the schematics. If a broken wire or faulty connector is not located, it is recommended that each termination be checked with a pair of tweezers.

5-22 If a broken wire is not found to be the cause, the next place to check is the power supply. Again, using the schematics, check for proper power supply voltages. One symptom of low voltage on the +5 volt supply is a flashing display which will not clear for more than one second when the reset button is pushed. If there is no +5 volt coming from the supply, on the 60-TF and 60-TFD only, the LED's and the display will not light, but the WWVB receiver will operate. You should be receiving 60 kHz as observed at the 60 kHz output. If the ±15 volts is not operating the display indicator LED's will light, but the WWVB receiver will not operate.

5-23 The 86-1 WWVB receiver board can be checked by injecting a 60 kHz signal, (AC coupled) into the antenna input and observing the 60 kHz output. With the gain control at maximum (counterclockwise) the gain of the receiver should be about 1.5×10^5.

5-24 In checking the assembly 86-30 "Local Standard Input", the first place to start is with the voltage readings noted on the schematic. Below are further areas which can be checked:

1. The VCXO output at pin 8 of U3 should be 3 volts P-P. with a local standard locked.
2. Look for 1 MHz at pin 11 of U5.
3. Check pin 4 of U1 for TTL output, at Local Standard frequency.
4. Check U11 by looking for negative pulses of about 400 nsec. at pin 12 coincident with the positive transition at pin 10, and a 200 nsec. negative pulse at pin 4 coincident with the negative transition at pin 1.
5. Check to be sure U12 is toggling correctly.

5-25 In checking assembly 86-31 "WWVB Input", after checking the voltage readings, check:

1. The VCXO output should be at pin 1 of U4.
2. U2 pin 14 for -0 v with no antenna.
3. U2 with no local standard connected, pin 7.
4. U6 for 1 MHz output at pin 1.
5. U8 for 240 kHz at pin 1.
6. U9 for 40 kHz at pin 10.
7. U9 for 20 kHz at pin 11 and 10 kHz at pin 12.
8. Q1 and Q2 for appropriate swings at edge connector pins U and T with and without an antenna.

5-26 Below are areas to check on board assembly 86-32 "Digital Phase Comparator":

1. U2 for 100 Hz at pin 12 when pins 2 and 3 are low and the 10 kHz input is present.
2. U4 for 100 Hz at pin 12 when 10 kHz input is present.

3. U5 pin 6 for bursts of 1 MHz at 100 Hz rate when pin 2 is high. It may be necessary to let the local standard loop drift by disconnecting the local standard to view this.
4. U6 and U7 for appropriate bursts at pins 11 and 12 respectively.
5. U9 that pin 5 is low when pin 2 is low and stays high after pin 2 goes high.
6. U9 that pin 8 is high if pin 12 leads pin 11.

5-27 The assembly 86-33 "Program Counter" can be checked in the following areas:

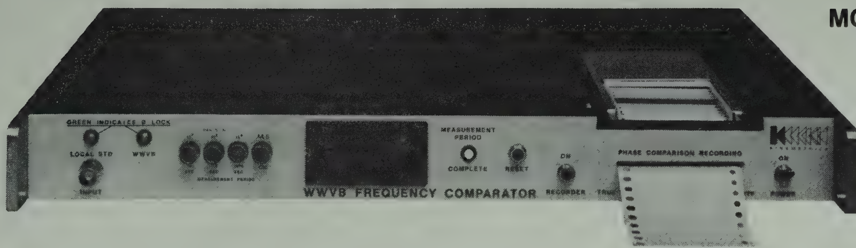
1. U1 pin 3 for 100 Hz bursts 100 msec/sec. pin 6 high except when pin 5 is high. Pin 8 high 100 mse/sec. pin 11, 100 Hz square wave.
2. U2 pin 12 for 10 Hz.
3. Pins 11, 12, 13, 14 for BCD counting on U3.
4. U4 pins 1 through 7, 9 and 10 for sequential 100 msec. low level.
5. U5 pin 8 for 1 Hz square wave.
6. U6 pin 1 for 100 msec. high per second. pin 4 for 100 msec. high per second when pin 6 is low. pin 10 for inverse of pin 8.
7. U7 pin 3 low during measurement. pin 5 low while reset button is pressed and goes high within 10 msec. after release.
8. U8, U9 and U10 check pins 12 for 0.1 Hz, 0.01 Hz and 0.001 Hz outputs.

5-28 If the failure can be narrowed down to one board, that board can be returned to the factory where it will be repaired and returned for a nominal charge. If the above efforts have failed to locate the source of the failure, the complete unit should be returned to the factory for repair.

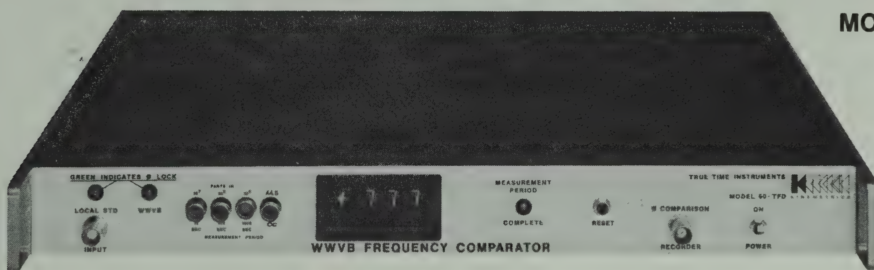
SECTION VI

SCHEMATIC AND PARTS LIST

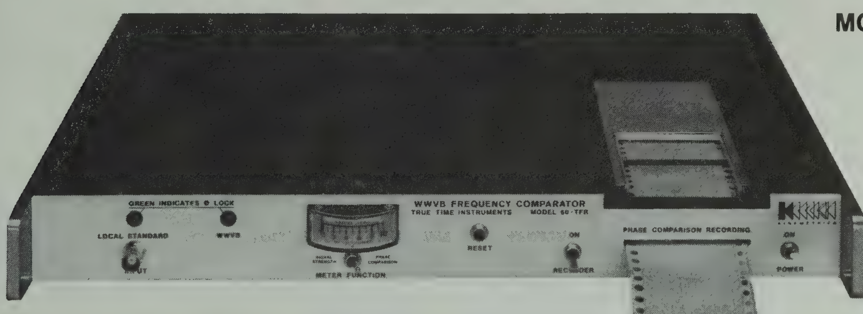
MODEL 60-TF, 60-TFD, 60-TFR, 60-TFC



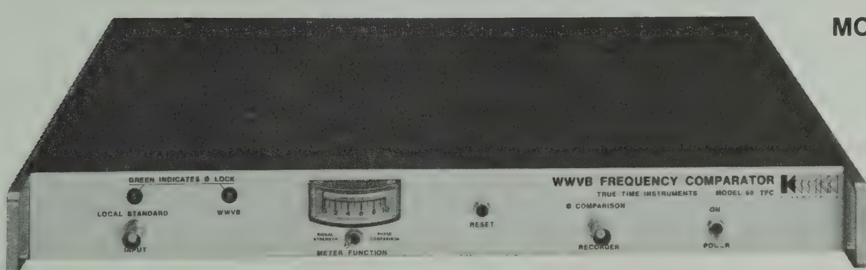
MODEL 60-TF



MODEL 60-TFD

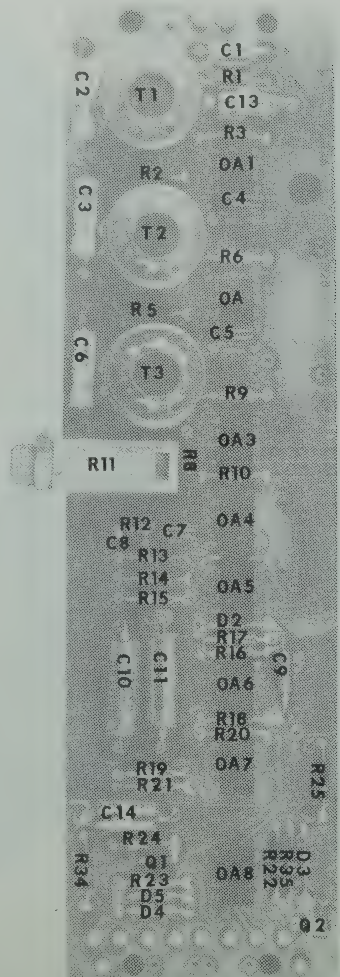


MODEL 60-TFR



MODEL 60-TFC

6-1 PARTS LOCATION ASSEMBLY 86-1



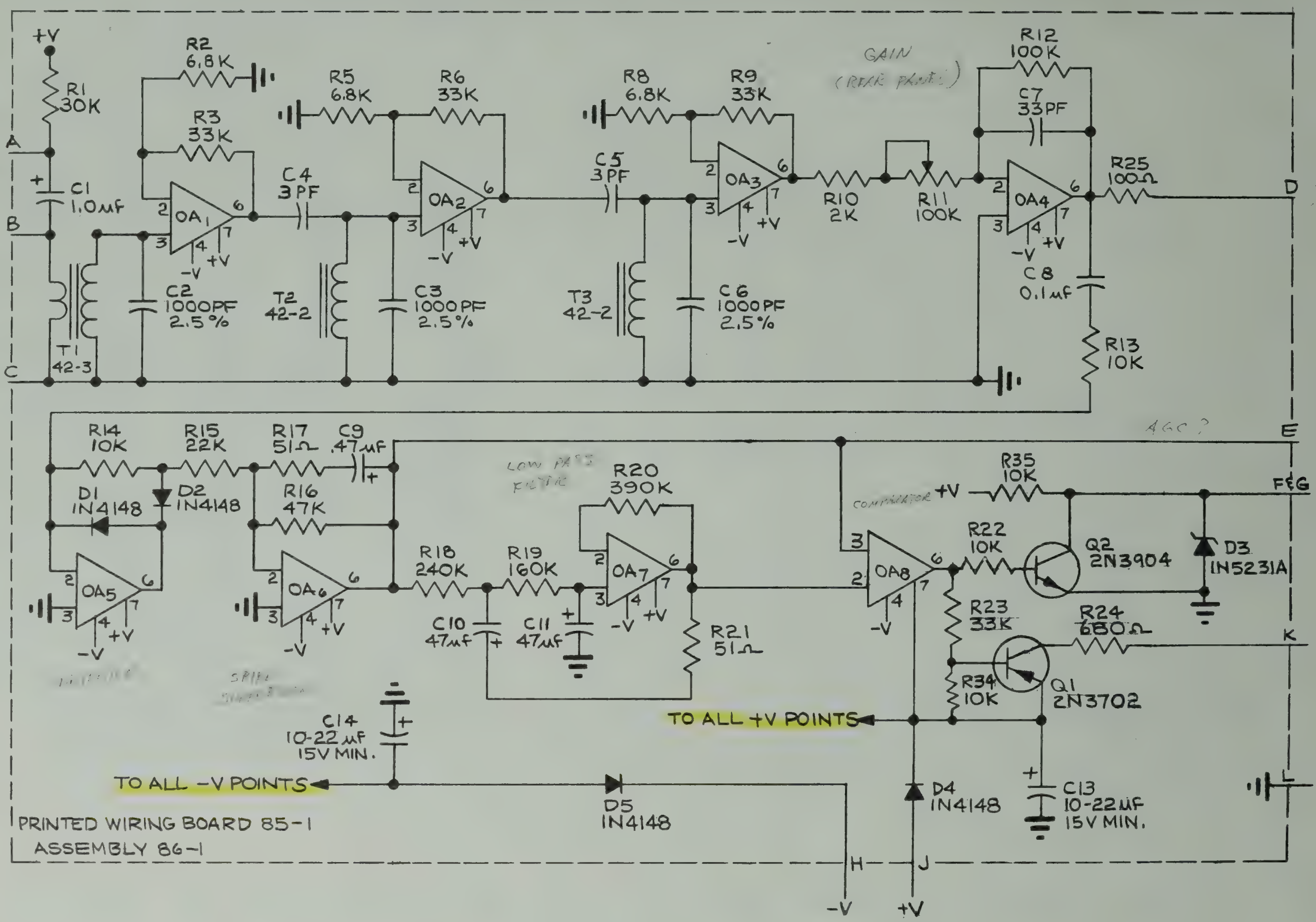
6-2 SYMBOL DESIGNATION REFERENCE 86-1

SYMBOL	TRUE TIME PART #	DESCRIPTION
C1	32-29	Cap. Tant. 1.0uf VDC
C2	24-1	Cap. Polystyrene 1000pf
C3	24-1	Cap. Polystyrene 1000pf
C4	29-3	Cap. Dipped Mica 3pf
C5	29-3	Cap. Dipped Mica 3pf
C6	24-1	Cap. Polystyrene 1000pf
C7	29-20	Cap. Dipped Mica 33pf
C8	36-94	Cap. Monolithic 0.1uf
C9	32-25	Cap. Tant 0.47uf VDC
C10	32-49	Cap. Tant 47uf VDC
C11	32-49	Cap. Tant 47uf VDC
C12	Not Used	
C13	23-10-25	Cap. Aluminum Electrolytic, 10uf 25V
C14	23-10-25	Cap. Aluminum Electrolytic, 10uf 25V
D1	57-4148	Diode, IN4148
D2	57-4148	Diode, IN4148
D3	55-5231	Diode, IN5231A
D4	57-4148	Diode, IN4148
D5	57-4148	Diode, IN4148
OA1	176-1	I.C. LF 351-N
OA2	176-1	I.C. LF 351-N
OA3	176-1	I.C. LF 351-N
OA4	176-1	I.C. LF 351-N
OA5	176-1	I.C. LF 351-N
OA6	176-1	I.C. LF 351-N
OA7	176-1	I.C. LF 351-N
OA8	176-1	I.C. LF 351-N
Q1	175-3702	Transistor MPS 3702
Q2	175-3904	Transistor, 2N3904
R1	2-108	Res. Carbon 30K ¼W +5%
R2	2-93	Resistor Carbon 6.8K ¼W +5%
R3	2-109	Resistor Carbon 33K ¼W +5%
R4	Not Used	
R5	2-93	Resistor Carbon 6.8K ¼W +5%
R6	2-109	Resistor Carbon 33K ¼W +5%
R7	Not Used	
R8	2-93	Resistor Carbon 6.8K ¼W +5%
R9	2-109	Resistor Carbon 33K ¼W +5%
R10	2-80	Resistor Carbon 2K ¼W +5%
R11	20-1	Pot Cermet 100K (Beckman #89PR100K)
R12	2-121	Resistor Carbon 100K ¼W +5%
R13	2-97	Resistor Carbon 10K ¼W +5%
R14	2-97	Resistor Carbon 10K ¼W +5%
R15	2-105	Resistor Carbon 22K ¼W +5%
R16	2-113	Resistor Carbon 47K ¼W +5%
R17	2-42	Resistor Carbon 51ohms ¼W +5%

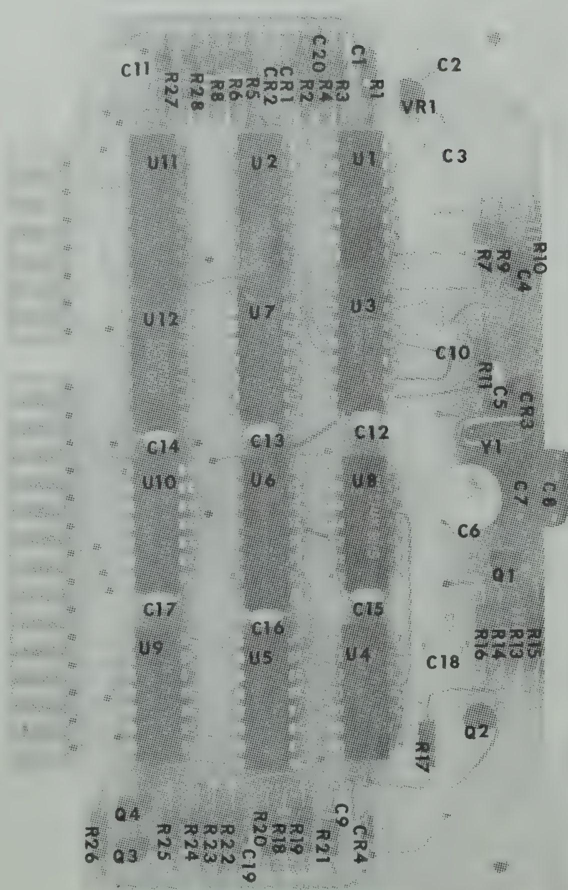
SYMBOL	TRUE TIME PART #	DESCRIPTION
R18	2-130	Resistor Carbon 240K ¼W+5%
R19	2-126	Resistor Carbon 160K ¼W+5%
R20	2-135	Resistor Carbon 390K ¼W+5%
R21	2-42	Resistor Carbon 51ohms ¼W +5%
R22	2-97	Resistor Carbon 10K ¼W +5%
R23	2-109	Resistor Carbon 33K ¼W +5%
R24	2-69	Resistor Carbon 680 ¼W+5%
R25	2-49	Resistor Carbon 100ohms ¼W +5%
R26-33	Not Used	
R34	2-97	Resistor Carbon 10K ¼W +5%
R35	2-97	Resistor Carbon 10K ¼W +5%
T1	42-3	Coil, R.F. Assembly
T2	42-2	Coil, R.F. Assembly
T3	42-2	Coil, R.F. Assembly
PWB	85-1	Printed Wiring Board 60kHz
	95-1	Plastic Cast, Trimpot Housing(Beckman #89-B)

TRF RCVR

6-3 SCHEMATIC ASSEMBLY 86-1



6-4 PARTS LOCATION ASSEMBLY 86-30

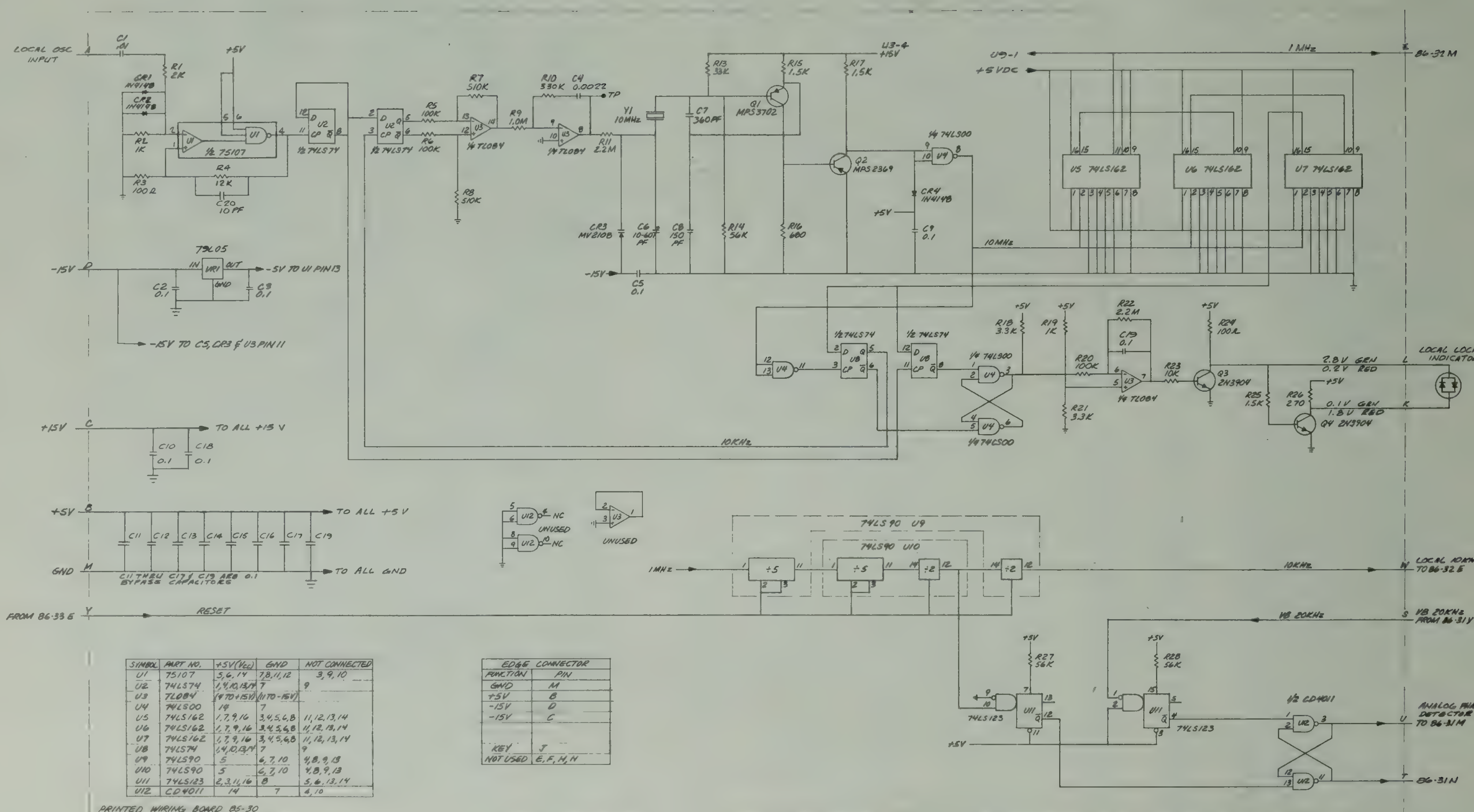


6-5 SYMBOL DESIGNATION REFERENCE 86-30

SYMBOL	TRUE TIME PART #	DESCRIPTION
C1	36-83	Cap. Ceramic 0.1uf
C2	36-95	Cap. Monolithic 0.1uf
C3	36-95	Cap. Monolithic 0.1uf
C4	36-66	Cap. Monolithic .0022uf
C5	36-95	Cap. Monolithic 0.1uf
C6	33-60	Ceramic Trimmer 10-60PF (Stettner Trush #10 Strik. 22 10-60)
C7	29-47	Cap. Dipped Mica 360PF
C8	29-37	Cap. Dipped Mica 150PF
C9	36-95	Cap. Monolithic 0.1uf
C10	36-95	Cap. Monolithic 0.1uf
C11	36-95	Cap. Monolithic 0.1uf
C12	36-95	Cap. Monolithic 0.1uf
C13	36-95	Cap. Monolithic 0.1uf
C14	36-95	Cap. Monolithic 0.1uf
C15	36-95	Cap. Monolithic 0.1uf
C16	36-95	Cap. Monolithic 0.1uf
C17	36-95	Cap. Monolithic 0.1uf
C18	36-95	Cap. Monolithic 0.1uf
C19	Not Used	
C20	29-10	Cap. Dipped Mica 10PF
CR1	57-1	Diode IN4148
CR2	57-1	Diode IN4148
CR3	35-08	Varicap, Motorola #MV2108
CR4	57-1	Diode IN4148
Q1	175-3702	Transistor MPS3702
Q2	175-2369	Transistor MPS2369
Q3	175-3904	Transistor 2N3904 or 2N3643
Q4	175-3904	Transistor 2N3904 or 2N3643
R1	Not Used	
R2	Not Used	
R3	2-49	Res. Carbon 100 ohm ¼W 5%
R4	2-99	Res. Carbon 12K ¼W 5%
R5	2-121	Res. Carbon 100K ¼W 5%
R6	2-121	Res. Carbon 100K ¼W 5%
R7	2-138	Res. Carbon 510K ¼W 5%
R8	2-138	Res. Carbon 510K ¼W 5%
R9	2-145	Res. Carbon 1Meg ¼W 5%
R10	2-121	Res. Carbon 100K ¼W 5%
R11	2-153	Res. Carbon 2.2Meg ¼W 5%
R12	Not Used	
R13	2-109	Res. Carbon 33K ¼W 5%
R14	2-115	Res. Carbon 56K ¼W 5%
R15	2-77	Res. Carbon 1.5K ¼W 5%
R16	2-69	Res. Carbon 680 ohm ¼W 5%
R17	2-77	Res. Carbon 1.5K ¼W 5%
R18	2-86	Res. Carbon 3.9K ¼W 5%
R19	2-73	Res. Carbon 1,0K ¼W 5%
R20	2-121	Res. Carbon 100K ¼W 5%
R21	2-86	Res. Carbon 3.9K ¼W 5%
R22	2-153	Res. Carbon 2.2Meg ¼W 5%
R23	2-97	Res. Carbon 10K ¼W 5%
R24	2-49	Res. Carbon 100 ohm ¼W 5%
R25	2-77	Res. Carbon 1.5K ¼W 5%
R26	2-59	Res. Carbon 270 ohm ¼W 5%
R27	2-115	Res. Carbon 56K ¼W 5%
R28	2-115	Res. Carbon 56K ¼W 5%
R29	Not Used	
U1	176-75107	I.C. 75107N
U2	176-7474	I.C. 74LS74
U3	176-084	I.C. TL 084
U4	176-00	I.C. 74LS00
U5	176-162	I.C. 74LS162
U6	176-162	I.C. 74LS162
U7	176-162	I.C. 74LS162
U8	176-7474	I.C. 74LS74
U9	176-7490	I.C. 7490 DIP
U10	176-7490	I.C. 7490 DIP
U11	176-74123	I.C. 74123 DIP
U12	176-4011	I.C. 4011
VR1	176-79L05	I.C. 79L05
Y1	59-10000	Crystal 10.000 MHz 32PF .001%
PWB	85-30	Printed Wiring Board

6-6 SCHEMATIC ASSEMBLY 86-30

LOCAL STD VCO

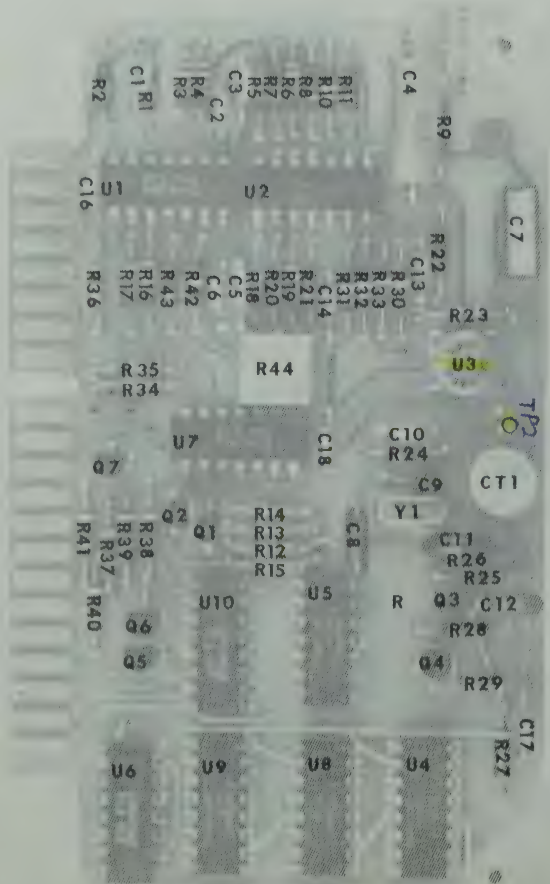


SYMBOL	PART NO.	+5V(Vcc)	GND	NOT CONNECTED
U1	75107	5,6,14	7,8,11,12	3,9,10
U2	74LS74	1,4,10,13,14	7	9
U3	TL084	(4 TO +15V)	(11 TO -15V)	
U4	74LS00	14	7	
U5	74LS162	1,7,9,16	3,4,5,6,8	11,12,13,14
U6	74LS162	1,7,9,16	3,4,5,6,8	11,12,13,14
U7	74LS162	1,7,9,16	3,4,5,6,8	11,12,13,14
U8	74LS74	1,4,10,13,14	7	9
U9	74LS90	5	6,7,10	4,8,9,13
U10	74LS90	5	6,7,10	4,8,9,13
U11	74LS123	2,3,11,16	8	5,6,13,14
U12	CD4011	14	7	4,10

PRINTED WIRING BOARD 85-30

EDGE CONNECTOR	
FUNCTION	PIN
GND	M
+5V	B
-15V	D
-15V	C
KEY	J
NOT USED	E,F,H,N

6-7 PARTS LOCATION ASSEMBLY 86-31



6-8 SYMBOL DESIGNATION REFERENCE 86-31

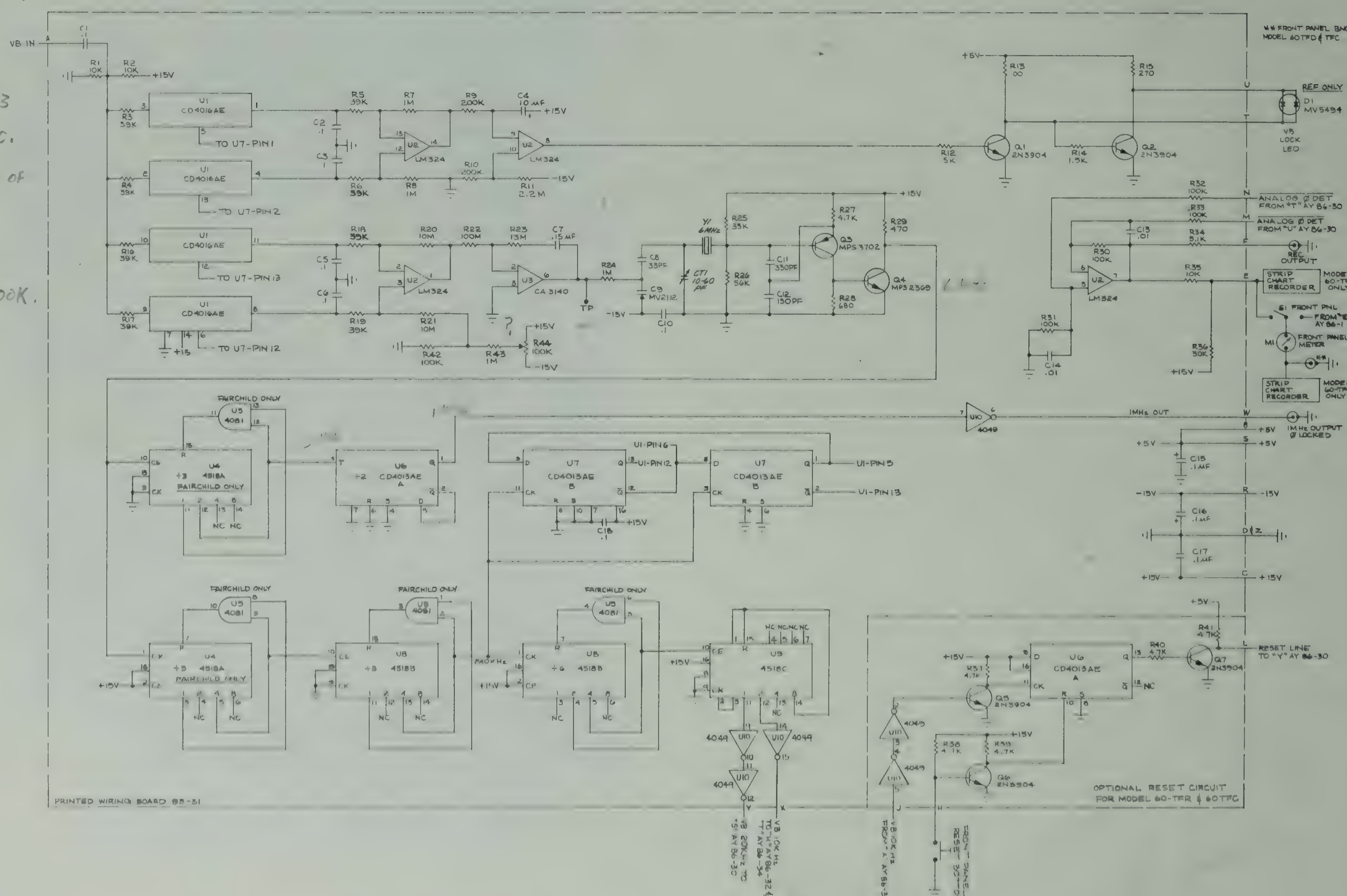
SYMBOL	TRUE TIME PART #	DESCRIPTION
C1	36-95	Cap. Monolithic .luf
C2	36-95	Cap. Monolithic .luf
C3	36-95	Cap. Monolithic .luf
C4	Not Used	
C5	36-95	Cap. Monolithic .luf
C6	36-95	Cap. Monolithic .luf
C7	28-15	Cap. Ployester .15uf
C8	29-20	Cap. Dipped Mica 33pf
C9	35-12	Varicap. Motorola #MV2112
C10	36-95	Cap. Monolithic .luf
C11	29-46	Cap. Dipped Mica 330pf
C12	29-37	Cap. Dipped Mica 150pf
C13	26-30	Cap. Cer. Disc. .01uf
C14	26-30	Cap. Cer. Disc. .01uf
C15	36-95	Cap. Monolithic .luf
C16	36-95	Cap. Monolithic .luf
C17	36-95	Cap. Monolithic .luf
C18	36-95	Cap. Monolithic .luf
CT1	33-60	Trimmer Ceramic, 10-60pf (Stettner Trush #10 Strik. 22 10-60)
PWB	85-31	Printed Wiring Board - WWVB Phase Lock
Q1	175-3904	Transistor 2N3904
Q2	175-3904	Transistor 2N3904
Q3	175-3702	Transistor MPS 3702
Q4	175-2369	Transistor MPS 2369
Q5	175-3904	Transistor 2N3904
Q6	Not Used	
Q7	175-3904	Transistor 2N3904
R1	2-97	Res. Carbon 10K ¼W ±5%
R2	2-97	Res. Carbon 10K ¼W ±5%
R3	2-111	Res. Carbon 39K ¼W ±5%
R4	2-111	Res. Carbon 39K ¼W ±5%
R5	2-111	Res. Carbon 39K ¼W ±5%
R6	2-111	Res. Carbon 39K ¼W ±5%
R7	2-145	Res. Carbon 1M ¼W ±5%
R8	2-145	Res. Carbon 1M ¼W ±5%
R9	2-128	Res. Carbon 200K ¼W ±5%
R10	2-128	Res. Carbon 200K ¼W ±5%
R11	2-153	Res. Carbon 2.2M ¼W ±5%
R12	2-101	Res. Carbon 15K ¼W ±5%
R13	2-49	Res. Carbon 100ohm ¼W ±5%
R14	2-77	Res. Carbon 1.5K ¼W ±5%
R15	2-59	Res. Carbon 270ohm ¼W ±5%
R16	2-111	Res. Carbon 1M ¼W ±5%
R17	2-111	Res. Carbon 1M ¼W ±5%
R18	2-111	Res. Carbon 39K ¼W ±5%
R19	2-111	Res. Carbon 39K ¼W ±5%

SYMBOL	TRUE TIME PART #	DESCRIPTION
R20	2-169	Res. Carbon 270ohm ¼W ±5%
R21	2-169	Res. Carbon 270ohm ¼W ±5%
R22	2-203	Res. Carbon 203 ¼W ±5%
R23	2-172	Res. Carbon 13M ¼W ±5%
R24	2-145	Res. Carbon 1M ¼W ±5%
R25	2-109	Res. Carbon 33K ¼W ±5%
R26	2-115	Res. Carbon 56K ¼W± 5%
R27	2-89	Res. Carbon 4.7K ¼W ±5%
R28	2-69	Res. Carbon 680ohm
R29	2-65	Res. Carbon 470ohm ¼W ±5
R30	2-121	Res. Carbon 100K ¼W ±5
R31	2-121	Res. Carbon 100K ¼W ±5
R32	2-121	Res. Carbon 100K ¼W ±5
R33	2-121	Res. Carbon 100K ¼W ±5
R34	2-90	Res. Carbon 5.1K
R35	2-97	Res. Carbon 10K ¼W ±5
R36	2-108	Res. Carbon 30K ¼W ±5%
R37	2-89	Res. Carbon 4.7K ¼W ±5%
R38	2-89	Res. Carbon 4.7K ¼W ±5%
R39	2-89	Res. Carbon 4.7K ¼W ±5%
R40	2-89	Res. Carbon 4.7K ¼W ±5%
R41	2-89	Res. Carbon 4.7K ¼W ±5%
R42	2-121	Res. Carbon 100K ¼W ±5%
R43	2-145	Res. Carbon 1M ¼W ±5%
R44	20-7	Pot Cerment 100K
U1	176-4016	I.C. RCA #CD4016AE
U2	176-324	I.C. National #LM324
U3	176-3140	I.C. RCA #CA3140T
U4	176-4518	I.C. Fairchild #F4518PC Only
U5	176-4081	I.C. Fairchild #F4081BPC Only
U6	176-4013	I.C. RCA #CD4013AE
U7	176-4013	I.C. RCA #CD4013AE
U8	176-4518	I.C. Fairchild #F4518PC Only
U9	176-4518	I.C. Fairchild #F4518PC Only
U10	176-4049	I.C. RCA #CD4049AE
Y1	59-6000	Crystal 6.000MHz

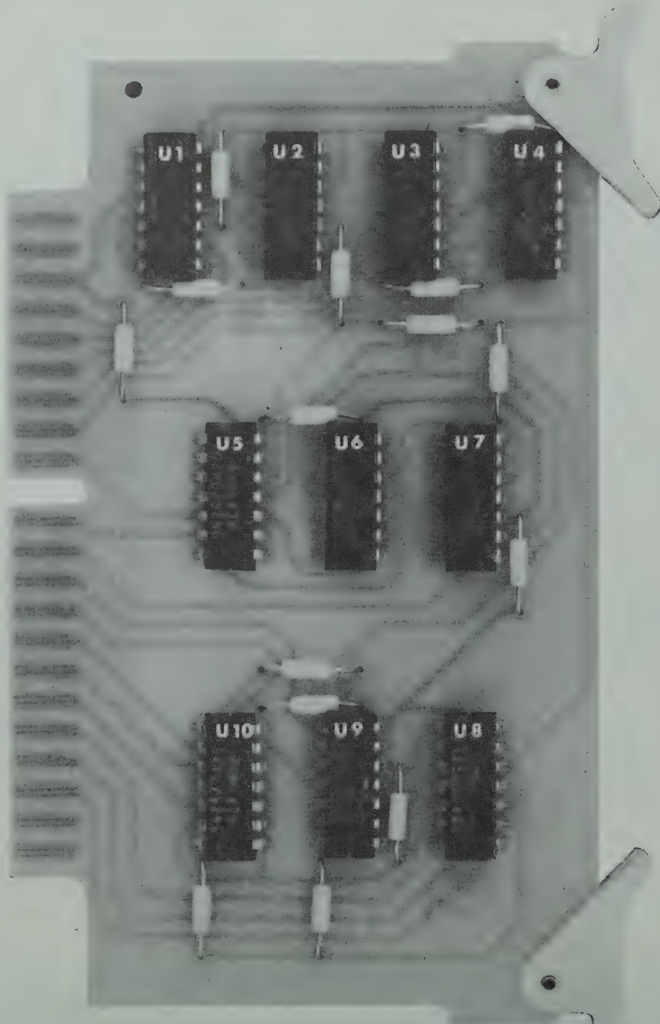
6-9 SCHEMATIC ASSEMBLY 86-31

WWVB VCO

R44 IS NULL
ADJ FOR U2 & U3
WITH ANTENNA DISC.
ADJ R44 FOR AVG OF
0VDC @ TP2
IF RANGE IS LOW,
CHANGE R43 TO 100K.



6-10 PARTS LOCATION ASSEMBLY 86-32

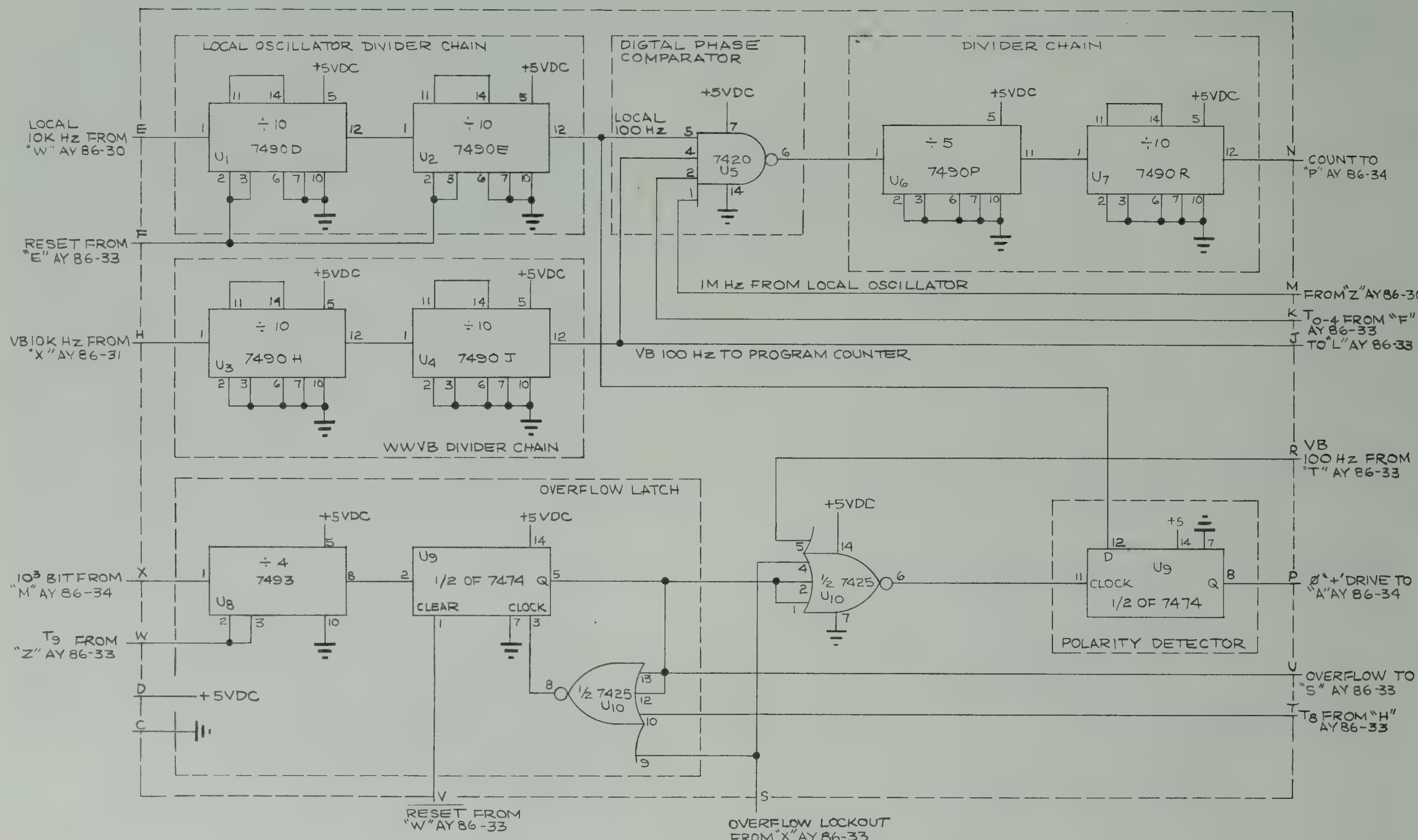


6-11 SYMBOL DESIGNATION REFERENCE 86-32

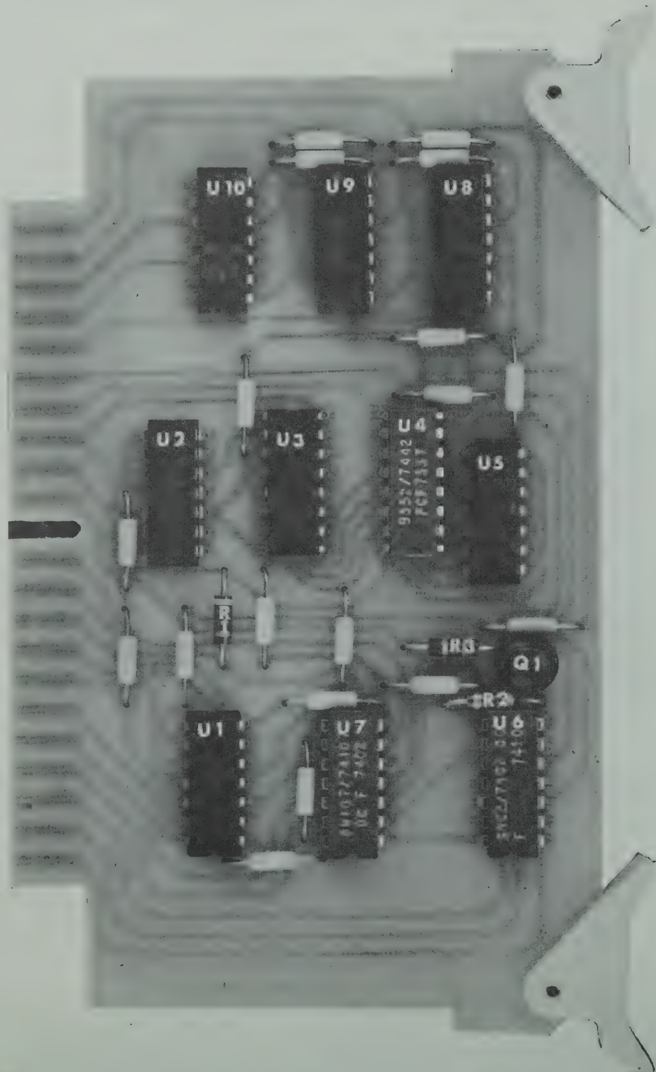
SYMBOL	TRUE TIME PART #	DESCRIPTION
U1	176-74LS90	I.C. 74LS90
U2	176-74LS90	I.C. 74LS90
U3	176-74LS90	I.C. 74LS90
U4	176-74LS90	I.C. 74LS90
U5	176-74LS20	I.C. 74LS20
U6	176-74LS90	I.C. 74LS90
U7	176-74LS90	I.C. 74LS90
U8	Not Used	
U9	176-74LS74	I.C. 74LS74
U10	176-7425	I.C. 7425 DIP
PWB	85-32	Printed Wiring Board
EJT	227-3	Ejector
JPR	2-0	Jumper

DIVIDER & PHASE COMPARATOR

6-12 SCHEMATIC ASSEMBLY 86-32



6-13 PARTS LOCATION ASSEMBLY 86-33

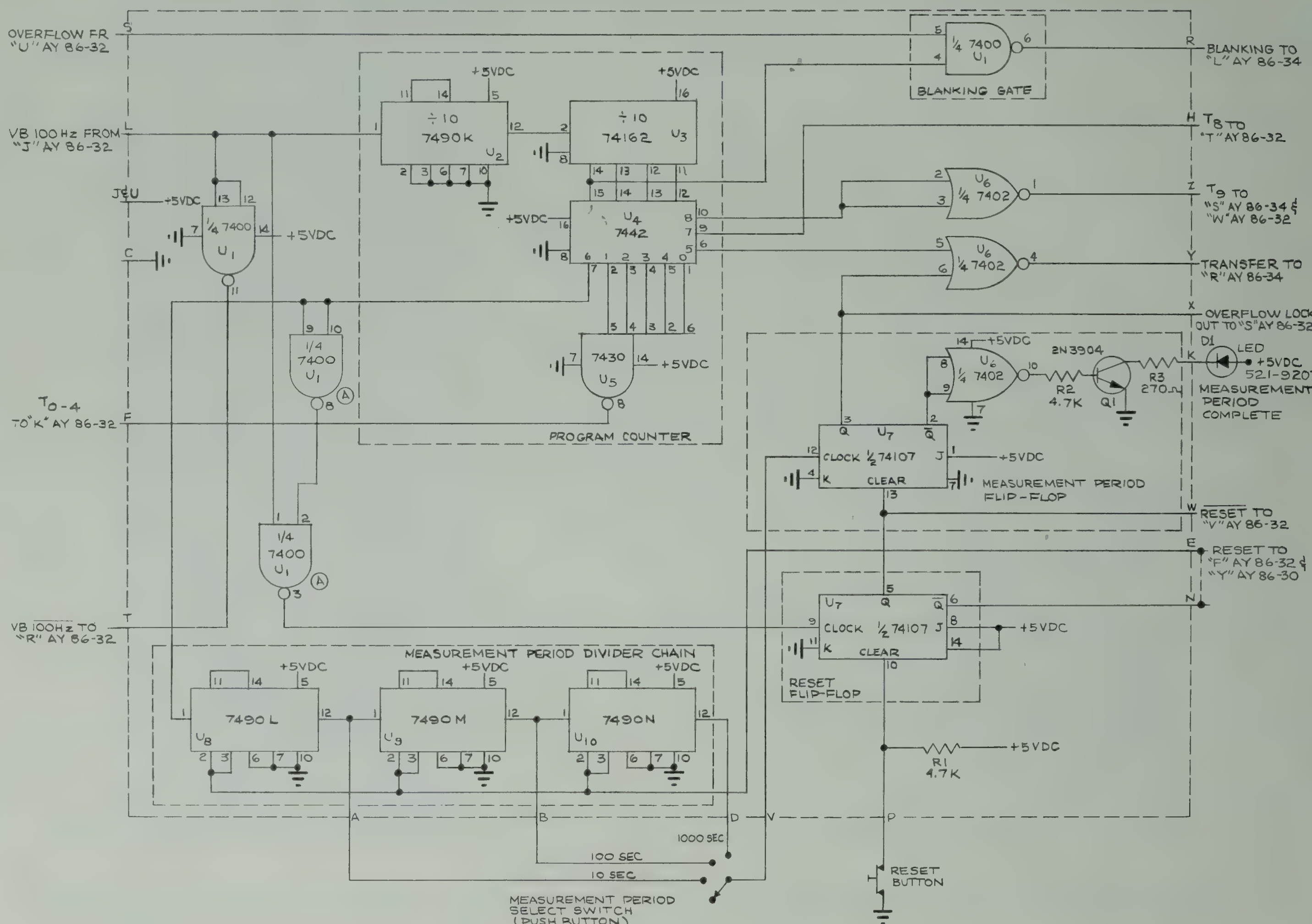


6-14 SYMBOL DESIGNATION REFERENCE 86-33

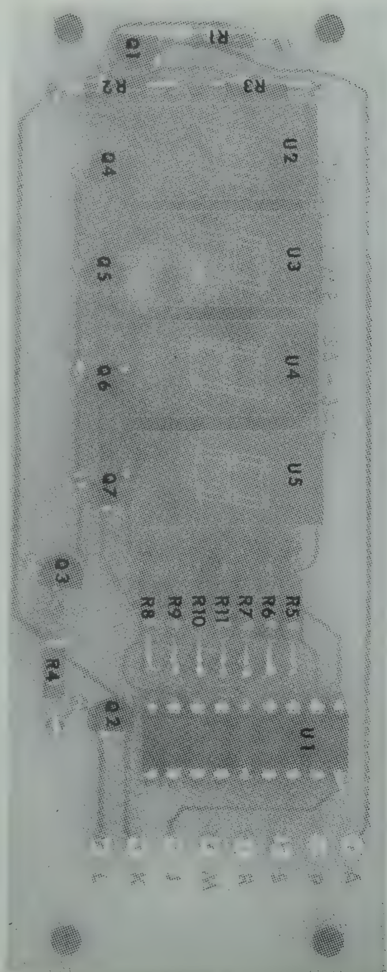
SYMBOL	TRUE TIME PART #	DESCRIPTION
D1	58-3	LED Yellow (DIALCO #521-9205
Q1	175-3904	2N3904 or 2N3643
R1	2-89	Res. Carbon 4.7K ¼W ±5%
R2	2-89	Res. Carbon 47K ¼W ±5%
R3	2-59	Res. Carbon 470 ohm ¼W ±5%
U1	176-74LS00	I.C. 74LS00 DIP
U2	176-74LS90	I.C. 74LS90 DIP
U3	176-74LS162	I.C.74LS162 DIP
U4	176-74LS42	I.C. 74LS42 DIP
U5	176-74LS30	I.C. 74LS30 DIP
U6	176-74LS02	I.C. 74LS02 DIP
U7	176-74107	I.C. 74107 DIP
U8	176-74LS90	I.C. 74LS90 DIP
U9	176-74LS90	I.C. 74LS90 Dip
U10	176-74LS90	I.C. 74LS90 DIP
PWB	85-33	Printed Wiring Board
JPR	2-0	Jumpers

PROGRAM COUNTER & CONTROL

6-15 SCHEMATIC ASSEMBLY 86-33



6-16 PARTS LOCATION ASSEMBLY 86-34

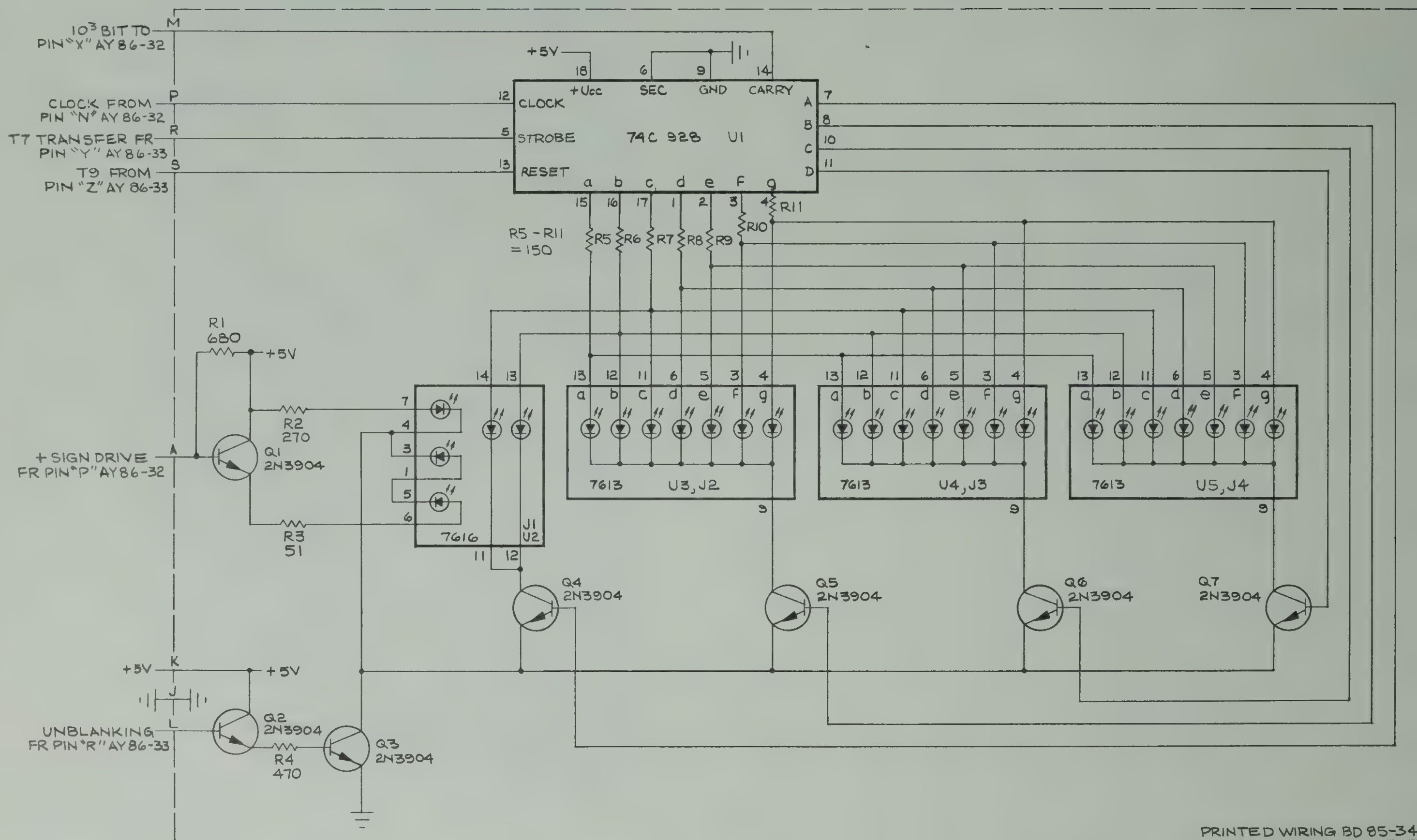


6-17 SYMBOL DESIGNATION REFERENCE 86-34

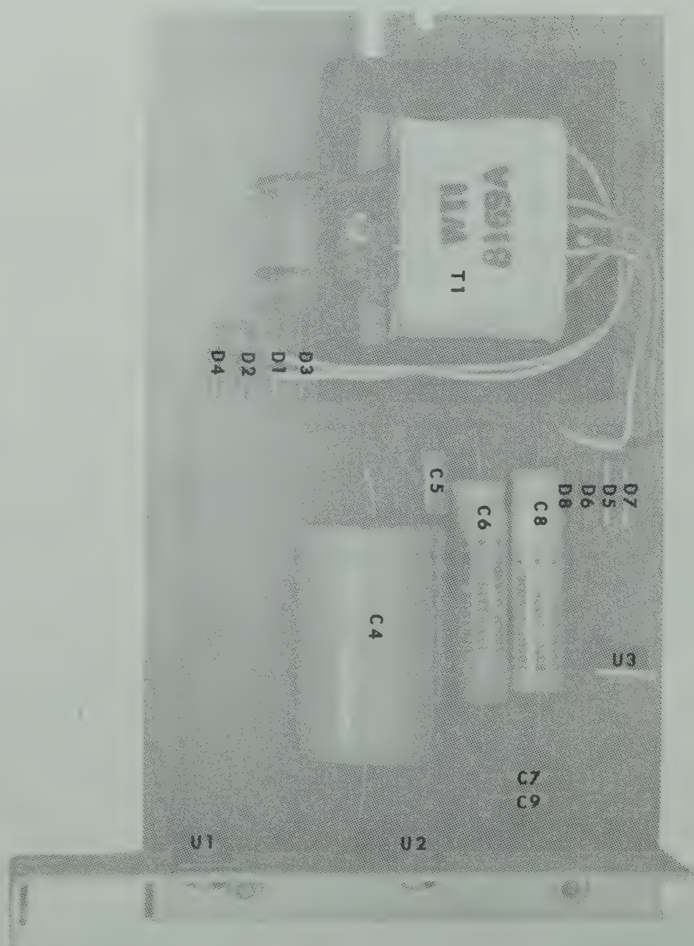
SYMBOL	TRUE TIME PART #	DESCRIPTION
Q1	175-3904	Transistor 2N3904
R1	2-69	Resistor Carbon 680 ohm ¼W ±5%
R2	2-59	Resistor Carbon 270 ohm ¼W ±5%
R3	2-42	Resistor Carbon 51 ohm ¼W ±5%
R4	2-65	Resistor Carbon 470 ohm ¼W ±5%
R5	2-53	Resistor Carbon 150 ohm ¼W ±5%
R6	2-53	Resistor Carbon 150 ohm ¼W ±5%
R7	2-53	Resistor Carbon 150 ohm ¼W ±5%
R8	2-53	Resistor Carbon 150 ohm ¼W ±5%
R9	2-53	Resistor Carbon 150 ohm ¼W ±5%
R10	2-53	Resistor Carbon 150 ohm ¼W ±5%
R11	2-53	Resistor Carbon 150 ohm ¼W ±5%
U1	176-74C928	I.C. 74C928
U2	176-7616	± 1 Segment LED (HP#5082-7616)
U3	176-7613	7 Segment LED (HP#5082-7613)
U4	176-7613	7 Segment LED (HP#5082-7613)
U5	176-7613	7 Segment LED (HP#5082-7613)
PWB	85-34	Printed Wiring Board Display
J1	379-14	Socket 14 Pin I.C.
J2	379-14	Socket 14 Pin I.C.
J3	379-14	Socket 14 Pin I.C.
J4	379-14	Socket 14 Pin I.C.

6-18 SCHEMATIC ASSEMBLY 86-34

DISPLAY BOARD



6-19 PARTS LOCATION ASSEMBLY 86-50

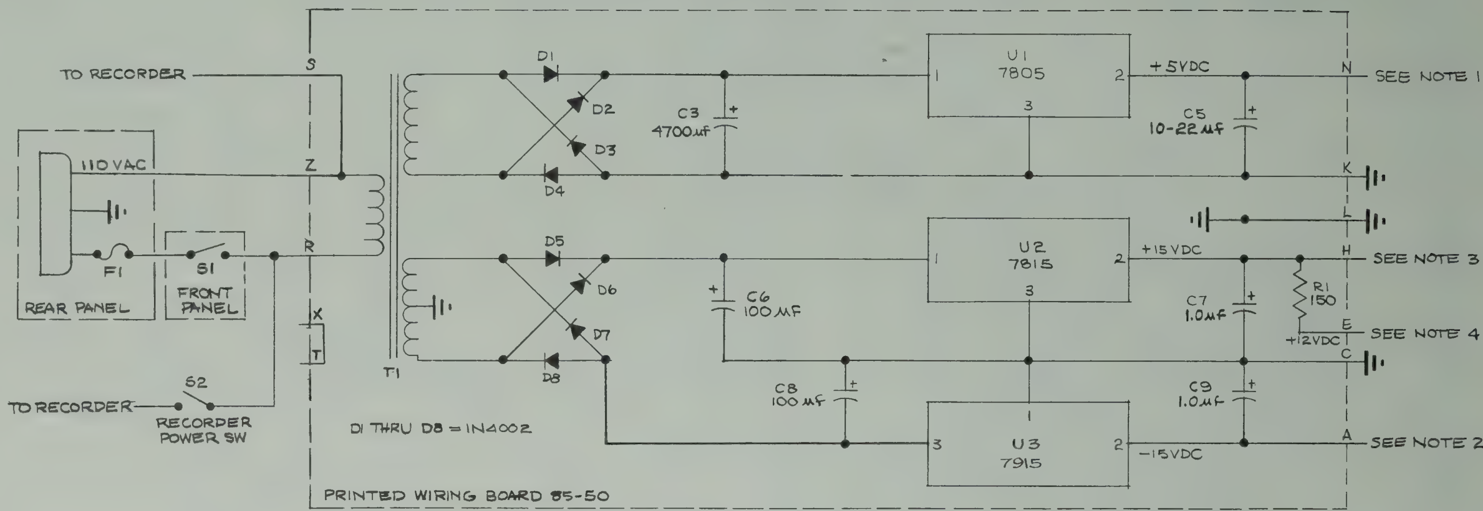


6-20 SYMBOL DESIGNATION REFERENCE 86-50

SYMBOL	TRUE TIME PART #	DESCRIPTION
C1	Not Used	
C2	Not Used	
C3	23-4700-25	Cap. Electro 4700 uf 25V
C4	Not Used	
C5	23-10-25	Cap. Alum. Electro, 10uf 25V
C6	23-100-35	Cap. Electro 100uf 35V
C7	32-29	Cap. Tant. 1uf 15V
C8	23-100-35	Cap. Electro 100uf 35V
C9	32029	Cap. Tant. 1uf 15V
D1	57-4005	Diode IN4005
D2	57-4005	Diode IN4005
D3	57-4005	Diode IN4005
D4	57-4005	Diode IN4005
D5	57-4005	Diode IN4005
D6	57-4005	Diode In4005
D7	57-4005	Diode IN4005
D8	57-4005	Diode IN4005
R1	2-53	Res. Carbon 150 ohms ¼W ±5%
T1	54-1	Power Transformer
U1	176-7805	I.C. +5V Regulator (Fairchild #7805CT)
U2	176-7815	I.C. +15V Regulator (Fairchild #7815UC)
U3	176-7915	I.C. -15V Regulator (Fairchild #79M15UC)
PWB	85-50	Printed Wiring Board
Brac.	206-7	Power supply mounting
Scr.	240-4-2	4-40 x ¼" Long PHMS
Scr.	240-4-8	4-40 x 1" Long PHMS
Scr.	240-4-3	4-40 x 3/8" Long PHMS
Spacer	270-4-2	#4 x 1/8" Long, Nylon
Nut	252-4	4-40 Hex
Lock Wash.	265-4	#4 Internal
Was.	253-4	#4 Flat
Comp.	281-1	Termal
Tie	232-1	Wrap

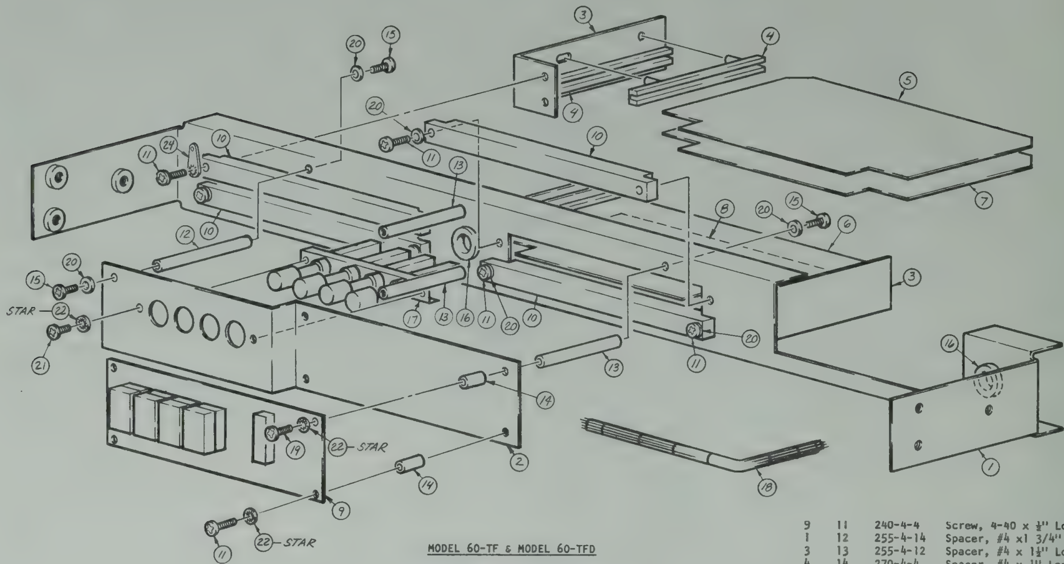
6-21 SCHEMATIC ASSEMBLY 86-50

POWER SUPPLY



4. CONNECTS TO ASSEMBLY 68-1.
3. CONNECTS TO THE FOLLOWING ASSEMBLYS: 86-30 AND 86-31.
2. CONNECTS TO THE FOLLOWING ASSEMBLYS: 86-1, 86-30 AND 86-31.
1. CONNECTS TO THE FOLLOWING ASSEMBLYS:
86-30, 86-31, 86-32, 86-33 AND 86-34.
NOTES: UNLESS OTHERWISE SPECIFIED

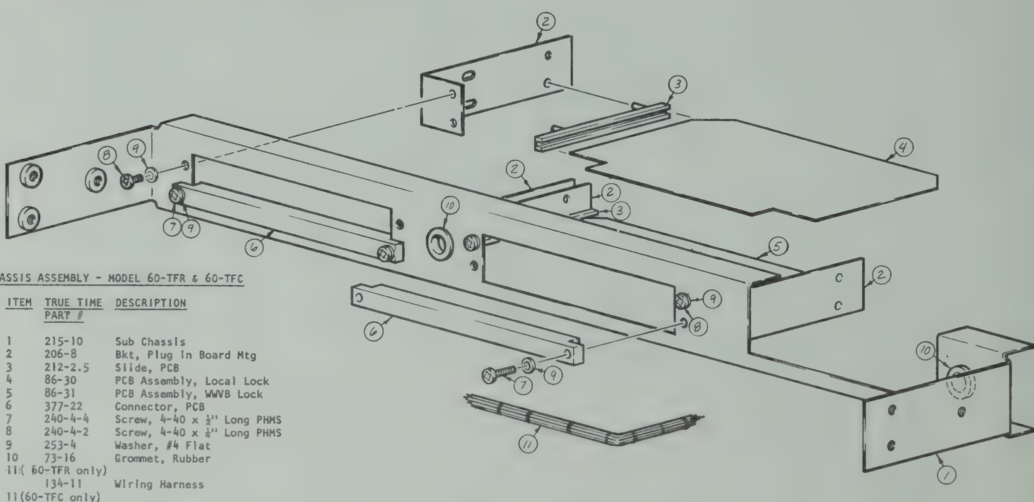
6-22 SUBCHASSIS ASSEMBLY 221-10 AND PARTS LIST MODELS 60-TF & 60-TFD



MODEL 60-TF & MODEL 60-TFD

QTY	ITEM	TRUE TIME PART #	DESCRIPTION
1	1	215-10	Sub Chassis
1	2	206-9	Bracket, Switch and Display Mtg.
4	3	206-8	Bracket, Plug In Board Mtg.
8	4	212-2.5	Slide, PCB
1	5	86-30	PCB Assy, Local Input
1	6	86-31	PCB Assy, VB Input
1	7	86-32	PCB Assy, Dig. Ø Comp.
1	8	86-33	PCB Assy, Program Counter
1	9	86-34	PCB Assy, Display
4	10	377-22	Connector. PCB
9	11	240-4-4	Screw, 4-40 x ½" Long, PHMS
1	12	255-4-14	Spacer, #4 x1 3/4" Long Alum.
3	13	255-4-12	Spacer, #4 x 1½" Long, Alum.
4	14	270-4-4	Spacer, #4 x ½" Long, Nylon
5	15	240-4-3	Screw, 4-40 x 3/8" Long, PHMS
2	16	73-16	Grommet, Rubber
1	17	64-5	Switch, 4 positions PC
1	18 (60-TF only)	134-10	Wiring Harness
1	18 (60-TFD only)	134-12	Wiring Harness
3	19	240-4-6	Screw, 4-40 x 5/8" Long,
11	20	253-4	Washer, #4 Flat
2	21	240-4-2	Screw, 4-40 x ¼" Long,PH
6	22	265-4	Lockwasher, #4 Internal
As Req'd	23	282-1	Locktite Adhesive (Not shown)
1	24	256-4	Solder Lug #4

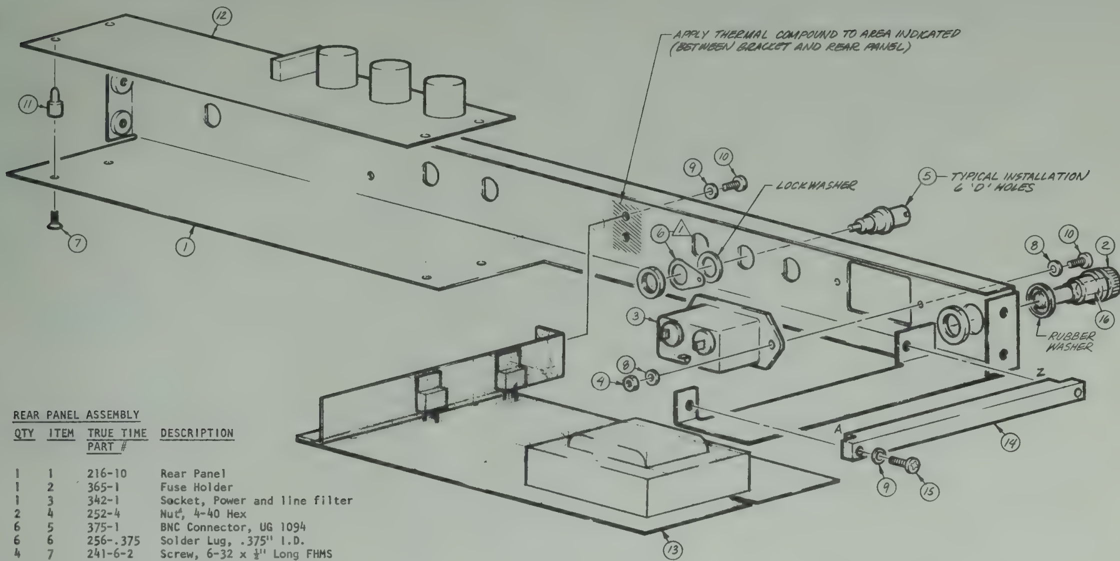
6-23 SUBCHASSIS ASSEMBLY 221-11 AND PARTS LIST MODELS 60-TFC & 60-TFR



SUBCHASSIS ASSEMBLY - MODEL 60-TFR & 60-TFC

QTY	ITEM	TRUE TIME PART #	DESCRIPTION
1	1	215-10	Sub Chassis
4	2	206-8	Bkt, Plug In Board Mtg
4	3	212-2.5	Slide, PCB
1	4	86-30	PCB Assembly, Local Lock
1	5	86-31	PCB Assembly, WWVB Lock
2	6	377-22	Connector, PCB
4	7	240-4-4	Screw, 4-40 x ½" Long PHMS
4	8	240-4-2	Screw, 4-40 x ¼" Long PHMS
8	9	253-4	Washer, #4 Flat
2	10	73-16	Grommet, Rubber
1	11 (60-TFR only)	134-11	Wiring Harness
1	11 (60-TFC only)	134-13	Wiring Harness

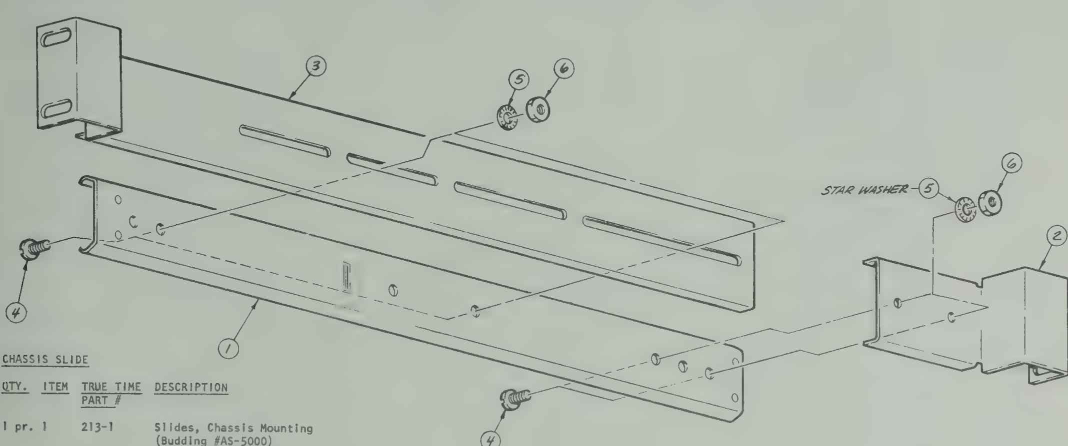
6-24 REAR PANEL ASSEMBLY 220-10 AND PARTS LIST MODELS 60-TF, 60-TFR, 60-TFD, 60-TFC



REAR PANEL ASSEMBLY

QTY	ITEM	TRUE TIME PART #	DESCRIPTION
1	1	216-10	Rear Panel
1	2	365-1	Fuse Holder
1	3	342-1	Socket, Power and line filter
2	4	252-4	Nut, 4-40 Hex
6	5	375-1	BNC Connector, UG 1094
6	6	256-.375	Solder Lug, .375" I.D.
4	7	241-6-2	Screw, 6-32 x ½" Long FHMS
4	8	265-4	Lockwasher, #4 Internal
4	9	253-4	Washer #4 Flat
4	10	240-4-3	Screw, 4-40 x 3/8" Long PHMS
4	11	277-2	Spacer, Circuit Board ½" Nylon
1	12	86-1	PCB Assembly, Receiver
1	13	86-50	Power Supply Board Assembly
1	14	377-22	Connector, PCB (Useco #1432-9-11
2	15	240-4-4	Screw, 4-40 x ½" Long PHMS
1	16	363-.750	Fuse, 3AG 3/4 AMP
As Req'd	17	282-1	Compound, Thermal (Not shown)
As Req'd	18	282-1	Locktite Adhesive (Not shown)

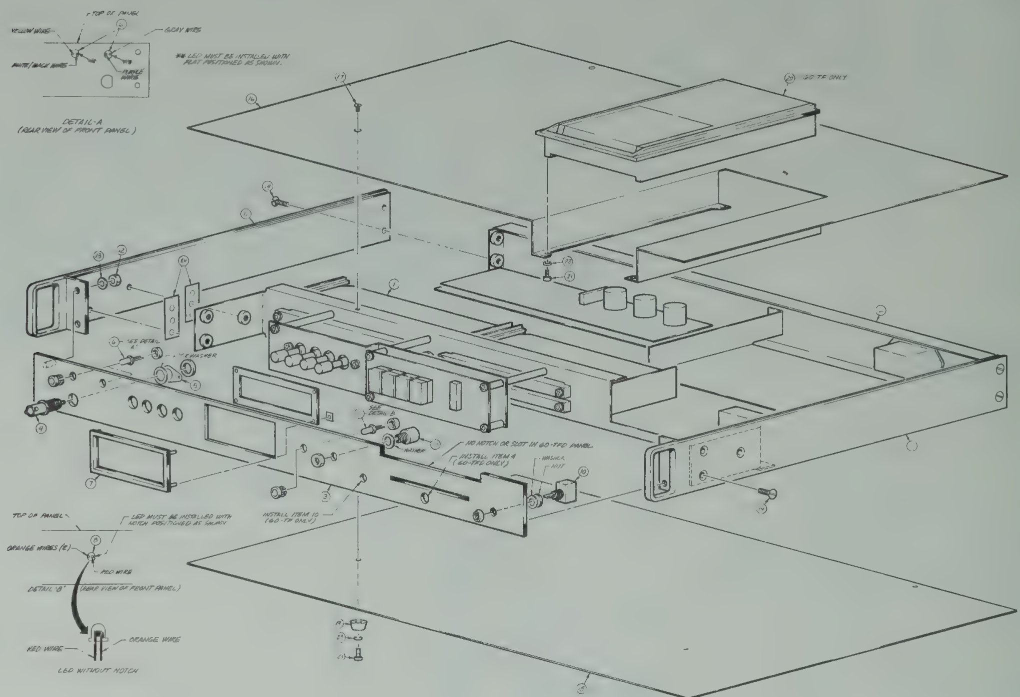
6-25 CHASSIS SLIDE KIT ASSEMBLY 150-1 AND PARTS LIST



CHASSIS SLIDE

QTY.	ITEM	TRUE TIME PART #	DESCRIPTION
1 pr.	1	213-1	Slides, Chassis Mounting (Budding #AS-5000)
2	2	206-10	Slide Mounting Bracket, Front
2	3	206-11	Slide Mounting Bracket, Rear
8	4	240-8-3	Screw, 8-32 x 3/8" Long PHMS
8	5	264-8	Lockwasher, #8, External
8	6	252-8	Nut, 8-32 Hex
4	7	241-10-3	Screw, 10-32 x 3/8" Long RHMS
4	8	248-10-2	Screw, 10-32 x ½" Long Hex Head
8	9	254-10	Lockwasher, #10 Split
8	10	252-10	Nut, 10-32 Hex
4	11	241-10-5	Screw, 10-32 x 5/8" Long PHMS
4	12	240-8-3	Screw, 8-32 x 3/8" Long PHMS
2	13	206-5	End Fitting, Rack Mounting

6-26 FINAL ASSEMBLY 151-10 & 151-12 AND PARTS LISTS MODELS 60-TF & 60-TFD



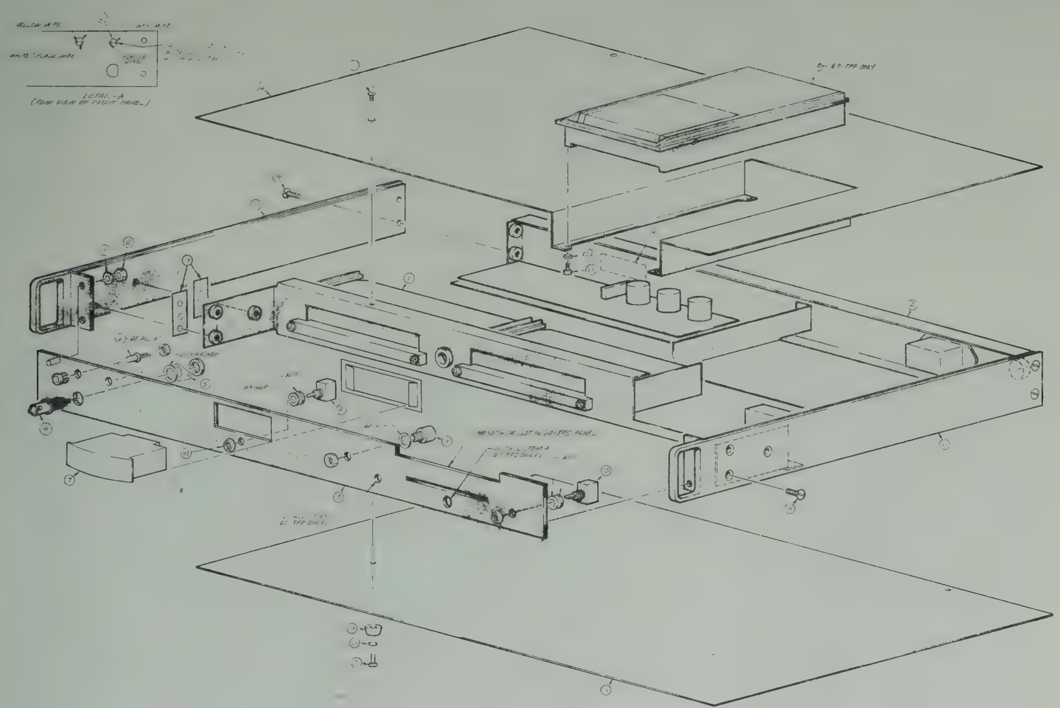
60-TF

QTY.	ITEM	TRUE TIME PART #	DESCRIPTION
1	1	221-10	Sub Chassis Assembly
1	2	220-10	Rear Panel Assembly
1	3	100-10	Panel, Front
1	4	375-1	Connector, BNC UG1094
1	5	256-.375	Solder Lug, .375" I.D.
2	6	58-2	LED Red/Green (Wyle# MV5491 (w/hdwe)
1	7	210-1	Bezel, Display
1	8	58-3	LED, Yellow (Rose Elec. #9AMH LED (AND 1134)
1	9	64-2	Switch, Push Button SPST (Fisher Brownell)
2	10	60-1	Switch, SPDT (Fisher Brownell 7101-P3)
2	11	217-10	Plate, Mounting Side
4	12	252-8	Nut, #8-32 (small) Hex
4	13	254-8	Lockwasher, #8 Split
10	14	241-8-5	Screw, 8-32 x 5/8" Long PHMS
1	15	203-2	Cover, Bottom
1	16	203-3	Cover, Top
9	17	249-1	Screw, 4-40 x ¼" Long FHMS
Not Used			
4	19	261-1	Rubber Feet
1	20	347-1	Recorder Strip Chart (Amprobe #FDB81-1" (60 cy. 115VAC)
4	21	240-4-3	Screw, 4-40 x 3/8" Long PHMS
4	22	265-4	Lockwasher, #4 Internal
4	23	253-4	Washer, #4 Flat
As Req'd	24	263-1	Shim Chassis
As Req'd	25	282-1	Locktite Adhesive (not shown)
Not Used			
1	27	332-2	Power Cord (Wyle Belden #17250)
Not Used			
1	29	400-1	Label Product I.D.
Not Used			
1	31	150-1	Chassis Slide Kit

60-TFD

QTY	ITEM	TRUE TIME PART #	DESCRIPTION
1	1	221-10	Sub Chassis Assembly
1	2	220-10	Rear Panel Assembly
1	3	100-12	Panel, Front
2	4	375-1	Connector, BNC UG1094
2	5	256-.375	Solder Lug, .375" I.D.
2	6	58-2	LED, Red/Green (Wyle# MV5491 w/hdwe)
1	7	210-1	Bezel, Display (Rose Elec. #910-15)
1	8	58-3	LED, Yellow (Rose Elec. #9AMH LED AND 1134)
1	9	64-2	Switch, Push Button SPST (Fisher Brownell)
1	10	60-1	Switch, DPDT (Fisher Brownell #7101-P3)
2	11	217-10	Plate, Mounting Side
4	12	258-8	Nut #8-32 (small) Hex
4	13	254-8	Lock Washer #8 Split
10	14	241-8-5	Screw, 8-32 x 5/8" Long PHMS
1	15	203-2	Cover, Bottom
1	16	203-5	Cover, Top
5	17	249-1	Screw, 4-40 x ¼ Long FHMS (Black)
1	18	363-.750	Fuse, 3AG 3/4 Amp
4	19	261-1	Feet, Rubber
Not Used			
4	21	240-4-3	Screw, 4-40 x 3/8" Long PHMS
Not Used			
4	23	253-4	Washer, #4 Flat
As Req'd	24	263-1	Shim, Chassis
As Req'd	25	282-1	Locktite Adhesive (Not shown)
4	26	249-1	Screw, 4-40 x ¼" Long FHMS (Black)
1	27	332-2	Power Cord (Wyle Belden #17250)
2	28	206-1	End Fitting, Rack Mounting
1	29	400-1	Label, Product I.D.

6-27 FINAL ASSEMBLY 151-11 & 151-13 AND PARTS LISTS MODELS 60-TFC & 60-TFR



60-TFR

QTY	ITEM	TRUE TIME PART #	DESCRIPTION
1	1	221-11	Sub Chassis Assembly
1	2	220-10	Rear Panel Assembly
1	3	100-11	Panel, Front
1	4	375-1	Connector, BNC UG1094
2	5	256-.375	Solder Lug, .375" I.D.
2	6	58-2	LED Red/Green (Wyle # MV5491 w/hdwe)
1	7	344-1	Meter, Signal Strength (Emico #EM5128)
1	8	60-3	Switch, TPDT (Newark #7301 (SYZQ)
1	9	64-2	Switch, Push Button SPST (Fisher Brownell)
2	10	60-1	Switch DPDT (Fisher Brownell #7101-P3)
2	11	217-10	Plate, Mounting, Side
4	12	252-8	Nut, 8-32 (small) Hex
4	13	254-8	Lockwasher #8 Split
10	14	241-8-5	Screw, 8-32 x 5/8" Long PHMS
1	16	203-3	Cover, Top
9	17	249-1	Screw, 4-40 x ¼" Long FHMS
Not Used			
4	19	261-1	Rubber Feet
1	20	347-1	Recorder, Strip Chart (Amprobe #FDB81-1" (60cy. 115VAC)
4	21	240-4-3	Screw, 4-40 x 3/8" Long PHMS
4	22	265-4	Lockwasher, #4 Internal
4	23	253-4	Washer, #4 Flat
As Req'd	24	263-1	Shim, Chassis
As Req'd	25	282-1	Locktite Adhesive (not shown)
Not Used			
1	27	332-2	Power Cord (Wyle Belden #17250)
Not Used			
1	29	400-1	Lable, Product I.D.
Not Used			
1	31	150-1	Chassis Slide Kit
32-42 Not Used			
1	43	251-1	Nut, Dress

60-TFC

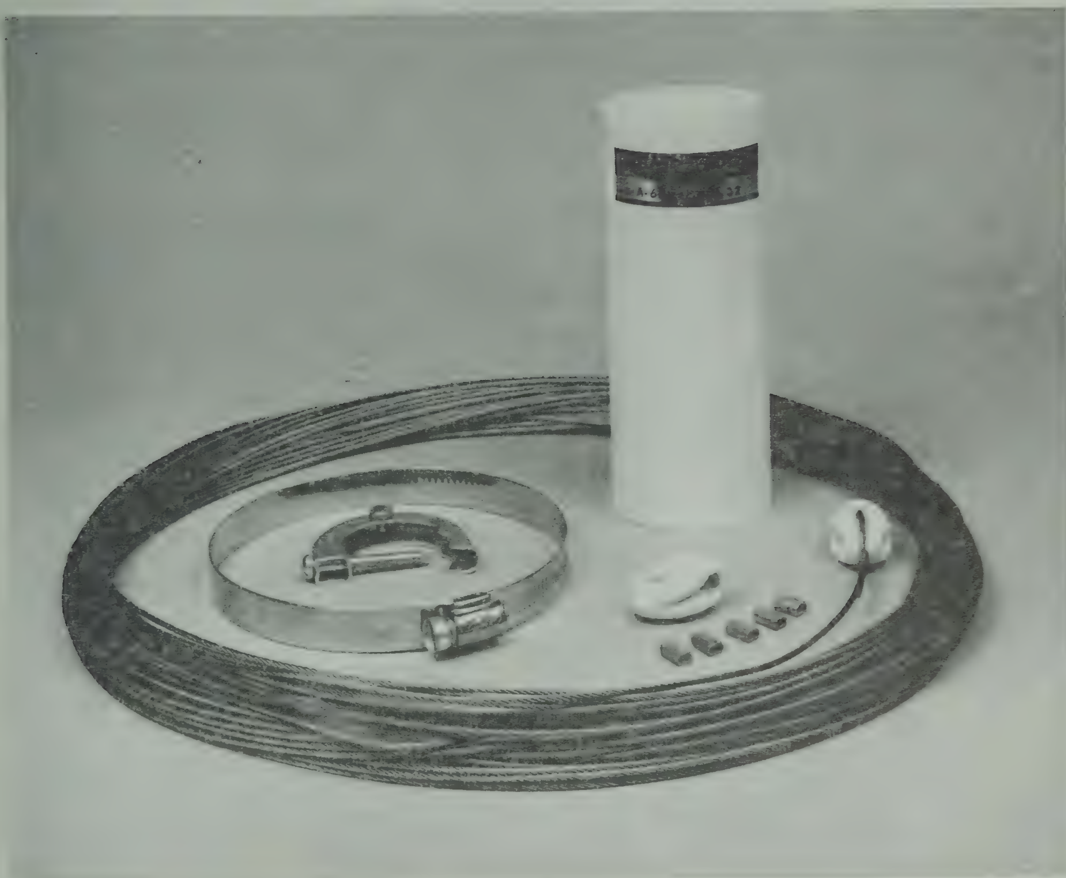
QTY	ITEM	TRUE TIME PART #	DESCRIPTION
1	1	221-11	Sub Chassis Assembly
1	2	220-10	Rear Panel Assembly
1	3	100-13	Panel, Front
2	4	375-1	Connector, BNC, UG1094
2	5	256-.375	Solder Lug, .375"I.D.
2	6	58-2	LED Red/Green (Wyle# MV5491 (w/hdwe)
1	7	344-1	Meter, Signal Strength (Emico #EM5128)
1	8	60-3	Switch, TPDT (Newark# 7301 (SUZQ)
1	9	64-2	Switch, Push Button SPST (Fisher Brownell)
1	10	60-1	Switch, DPDT (Fisher Brownell #7101-P3)
2	11	217-10	Plate, Mounting, Side
4	12	258-8	Nut, 8-32 (small)Hex
4	13	254-8	Lockwaher #8 Split
10	14	241-8-5	Screw, 8-32 x 5/8" Long PHMS
1	15	203-2	Cover, Bottom
1	16	203-5	Cover, Top
5	17	249-1	Screw, 4-40 x ¼" Long FHMS (Black)
1	18	363-.750	Fuse 3AG 3/4 Amp
4	19	261-1	Feet Rubber
Not Used			
4	21	240-4-3	Screw, 4-40 x 3/8" Long PHMS
Not Used			
4	23	253-4	Washer, #4 Flat
As Req'd	24	263-1	Shim, Chassis
As Req'd	25	282-1	Locktite Adhesive (not shown)
4	26	249-1	Screw, 4-40 x ½" Long FHMS (Black)
1	27	332-2	Power Cord (Wyle Belden #17250)
2	28	206-1	End Fitting, Rack Mounting
1	29	400-1	Label, Product I.D.
30-42 Not Used			
1	43	251-1	Nut, Dress

SECTION VII

ANTENNA INSTALLATION

AND SERVICE MANUAL

MODEL A-60LW



SECTION VII

ANTENNA INSTALLATION AND SERVICE MANUAL

MODEL A-60LW

7-1 INTRODUCTION

7-2 The Model A-60LW antenna is normally used in areas in which the signal strength is very weak or where noise interference problems exist. The first step in installation of your antenna is to check the nameplate on the unit and be certain you use the correct instructions for the antenna you have received. The installation instructions for the A-60LW are below, and the instructions for the Model A-60FS are found in Section VIII.

7-3 EQUIPMENT REQUIRED TO INSTALL MODEL A-60LW ANTENNA

(All equipment must operate at installation site)

- AC Voltmeter capable of reading 0.3 volt full scale at 60 kHz.
- Signal generator capable of 60.0 kHz with 6-7 volts P-P or an audio oscillator with the same capabilities.
- Large variable capacitor (to 1500 pf) or decade capacitance box capable of increments of 100 pf.
- Soldering iron.

7-4 INSTALLATION PROCEDURE

7-5 #1 - After the model of your antenna is determined to be A-60LW, the next step is the installation of the receiving wire. This antenna utilizes as its signal receiving device a length of antenna wire, 200 feet of wire is supplied with the antenna kit. The antenna wire, when installed should be a minimum of 75 feet, but if space is available a longer length would give a larger capture area and thus a stronger signal. The longer wire will also result in a better signal-to-noise ratio. In determining the orientation of the wire, the installer must first ascertain the compass heading for Fort Collins, Colorado from the installation site. This can be found using the Great Circle Map found in Section XI of this manual. When the compass heading has been determined <u>the antenna must point directly at Fort Collins</u>. Once the direction of orientation has been determined, the wire should be

a minimum of two or three feet above the roof or ground. Height above the ground is of no particular concern, and the two or three feet is adequate. Be certain not to bend the antenna around any corners in an effort to make it longer, as this will cancel out part of the signal received on the correctly oriented section of the Wire. (See the drawing on the following page.)

7-6 #2 - Attach the tuning box (PVC tube) to one of the supports on one end of the wire just installed. Mount the tube in such a way that moisture is least likely to enter the tube. The unit has been sealed at the factory and is relatively water resistant as long as care is taken in mounting it with the terminals facing downward.

7-7 #3 - Solder the wire antenna just installed to the terminal marked "A". The connection to the wire may be at any point on its length, but the distance from the antenna wire to the tuning box should be kept to a minimum. Connect the termianl on the antenna marked "G" to a good solid ground, using the excess antenna wire and the grounding clamp supplied. It is absolutely essential that this ground is provided.

7-8 #4 - The physical installation of the unit is now complete and all that is required is the tuning of the system for maximum reception of the 60 kHz signal. Connect the AC voltmeter to the output BNC on the antenna. Adjust the generator to 60 kHz using a counter to set the output accurately. Connect this generator to an auxiliary antenna which can be a length of 50 foot long hook-up wire laid near the long wire previously installed. When this antenna is fed with 7 to 8 volts P-P of 60 kHz from the oscillator it will provide a local source of 60 kHz strong enough to overcome any local noise at this frequency and strong enough to read on the voltmeter. Connect the variable capacitor across terminals "A" and "G" of the tuning box. Set the trimmer capacitor in the tuning box to its midpoint in capacitance, the maximum is marked by alignment of the two red dots. Tune the large variable capacitor or decade box until a sharp peak is noted on the AC volt meter*. Log the reading obtained on the voltmeter for reference later. Remove the variable capacitor or decade box and substitute a dipped mica capacitor for its exact value. After the dipped mica capacitor is soldered in place of the removed capacitor, trim the trimmer in the tuning box for peak reading on the voltmeter. Compare the reading now on the voltmeter with that logged earlier. If the antenna is now in tune,

the readings will be identical. If the two readings are not in agreement the tuning should be rechecked to determine if maximum has been achieved.

*NOTE: IF A SHARP PEAK CANNOT BE FOUND ON THE AC VOLTMETER REFER TO THE TROUBLESHOOTING PORTION OF THIS MANUAL.

7-9 #5 - This completes the installation of the antenna. It is recommended that RG-58/U be used as lead-in coax.

7-10 TROUBLESHOOTING MODEL A-60LW

7-11 #1 - In very rare instances of an extremely long antenna wire or a long wire to a ground source, it may be found that it is not possible to tune the antenna as previously described. This is due to the antenna-ground system resonating at a frequency lower than 60 kHz. If this symptom arises, first, check the ground connection, and if this appears to be in good condition, do the following:

a. Tune the generator driving the source antenna to a frequency lower than 60 kHz and see if a sharp peak can be found.
b. If this is found, return the generator to 60 kHz and connect the variable capacitor in series with the antenna and the Pin "A" on the tuning box.
c. The normal tuning procedure can now be accomplished using this series tuning capacitor.

7-12 #2 - Check the ground connection. This should be as short as possible to a good ground source.

7-13 GENERAL

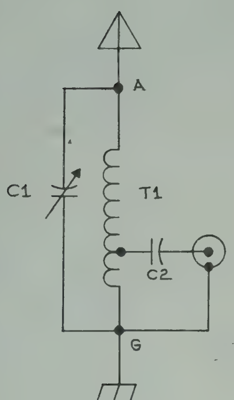
7-14 After tuning the antenna, if WWVB is not present on the receiver at the R.F. Test Point:

a. Be certain that the antenna wire is pointed <u>toward</u> Fort Collins, Colorado.
b. Check for a defective lead-in coax.
c. Try grounding the receiver case.
d. Moisture causing the antenna to become detuned by grounding out the antenna wire.

7-15 MAINTENANCE

7-16 The antenna tuning box Model A-60LW should not require service under normal operating conditions as it contains no active devices. If it should become evident that the unit is defective, it is best to return the tuning box to the factory for repair.

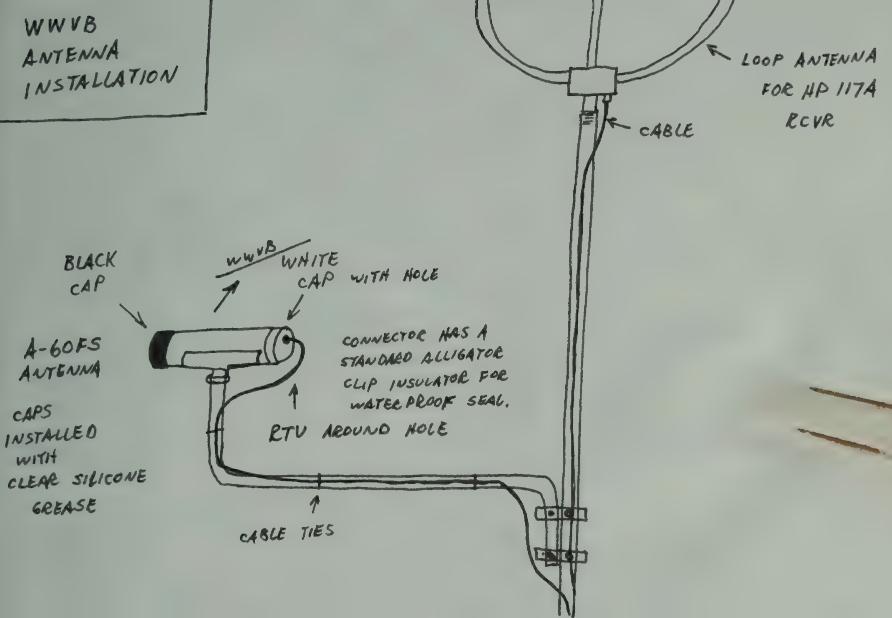
7-17 If it is not possible to return the unit, the end with the connector can be cut open with a small knife. After repair is complete, the end can be resealed with common PVC cement. The schematic and parts list is included below to assist in field repair.



QTY	ITEM	PART NO.	DESCRIPTION
1	C2	32-25	CAPACITOR, TANTALUM .47µF
1	C1	34-1	CAPACITOR, AIR VAR. 4.5-100PF
1	T1	42-5	COIL, ANTENNA TUNING, 8.2mH

Figure 7-1 A-60LW

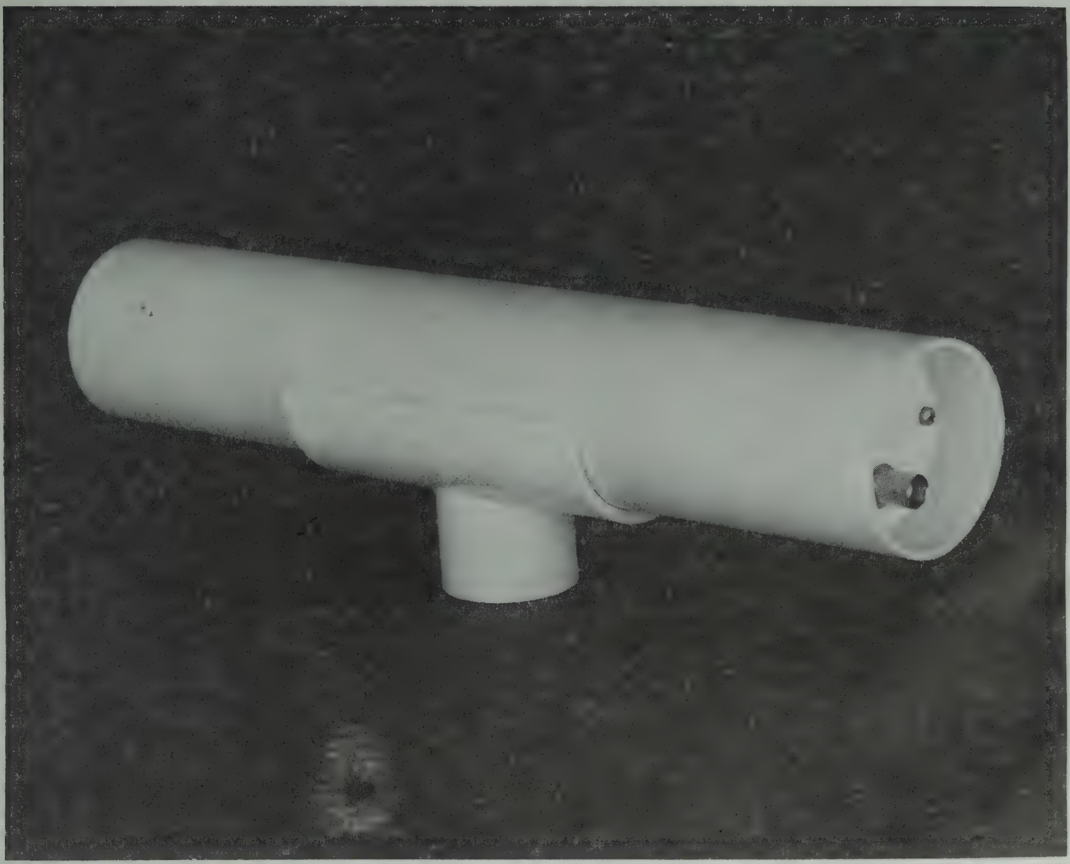
WWVB ANTENNA INSTALLATION



SECTION VIII

ANTENNA INSTALLATION
AND SERVICE MANUAL

MODEL A-60FS



SECTION VIII

ANTENNA INSTALLATION AND SERVICE MANUAL

MODEL A-60FS

8-1 INTRODUCTION

8-2 The Model A-60FS antenna is normally used in areas where the signal strength of WWVB is 100 μv/m or above. It is often used in applications which require it to be portable due to frequent moving of an installation. The first step in installing your antenna is to check the nameplate on the unit and the model number to be certain you are using the correct instructions for the antenna you have received. Model A-60FS instructions are below and the instructions for Model A-60LW are in Section VII.

8-3 Model A-60FS antenna has been specifically designed for operation with receivers manufactured by True Time Instrument Company. The factory should be consulted before connecting the antenna to any other receiver.

8-4 INSTALLATION

8-5 The installation of the antenna Model A-60FS requires only that the direction of Fort Collins, Colorado be determined and that the antenna be mounted horizontally as high in the air as is practical. The antenna is provided with a fitting which will allow it to be mounted on the end of a piece of common one-inch pipe. (1" Male Iron Pipe Thread) Once the unit is mounted, it should be directed such that the tubing points 90° from Fort Collins, Colorado. (The direction of Fort Collins can be determined by using the Great Circle Map included in this manual.) This orientation will allow the incoming signal to broadside the tube and obtain maximum reception.

8-6 When selecting a site for the antenna installation, several factors should be kept in mind. First, the antenna should be mounted a minimum of 25 feet from the receiver to prevent regeneration. Second, the antenna should not be mounted close to any steel structures (roof decking, pipes, air conditioning, etc.). Third, the signal-to-noise ratio will be improved by locating the antenna as far as practical from any local R.F. noise source (large electric motors, power lines, etc.). Finally,

in most cases the antenna will not be able to receive signal from WWVB is installed inside of a building, it must be outside.

8-7 After the unit is mounted, attach the lead-in coax (RG-58/U recommended) to the output BNC and the installation is complete. The antenna has been provided with a trimmer capacitor which has been factory tuned and locked for maximum reception. This antenna should not need retuning except in cases of extreme temperature, or after a long period of aging. Tuning procedure is included in the Maintenance Section of this manual.

8-8 MAINTENANCE

8-9 The Model A-60FS antenna contains a ferrite rod antenna coil and a preamp/line driver. The preamp contains only three active devices and should not require maintenance under normal conditions.

8-10 The antenna may need re-tuning when operating in extreme temperatures. Then it will be evident that the resonate frequency has shifted from the factory set 60 kHz, and this will cause a loss in signal strength. The best method of re-tuning the antenna is depicted in the block diagram below.

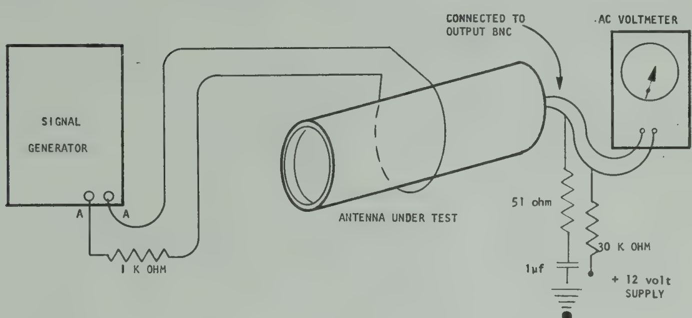


Figure 8-1 A60FS Block Diagram

8-11 Apply 12 volts through a 30K ohm resistor to the BNC connector, and couple in a 60.0 kHz signal by wrapping a single turn of wire around the center of the antenna. Connect the wire to the signal generator through a 1K ohm resistor; this resistor provides a constant current source.

8-12 This set-up and tuning should be performed at the approximate temperature the antenna is intended to operate. After the equipment is set-up as shown, remove the slot-head screw in the end of the antenna to allow access to the internal trimmer. The internal ceramic trimmer is adjusted with a small slot screwdriver. Tune the trimmer for maximum output at the BNC connector. Reinstall the screw. The antenna is now re-tuned for 60 kHz resonance at the temperature at which the tuning has been performed.

8-13 TROUBLESHOOTING

8-14 As mentioned in the Maintenance Section, the antenna contains only three active devices, all bipolar transistors. The most common types of failure that might be expected are:

a. Antenna has become de-tuned due to temperature extremes or aging.
b. Ferrite rod broken due to mechanical shock.
c. Failure of one of the devices.

8-15 The first step in determining the cause of antenna failure is to set-up the test equipment as shown in the block diagram in the Section above. With a 80mv (P-P) at generator output measured at Point AA, the antenna output should measure about 3.5mv at resonance on the A.C. Voltmeter (10mv P-P). If this level is not present, re-tune the trimmer to peak output. Once the resonance is set with the trimmer, the -3 db points should occur at ±500 Hz from resonance.

NOTE: Resonance frequency and Q will be shifted by nearby conductors; attempt to keep large conductors a minimum of 2 feet away from the antenna when in use or during test.

8-16 A broken ferrite rod will first become evident due to the inability to tune and obtain the proper output. To check for a broken rod, slowly increase the frequency of the generator and if the antenna resonance is found above 61 kHz, the cause is most likely a broken ferrite rod.

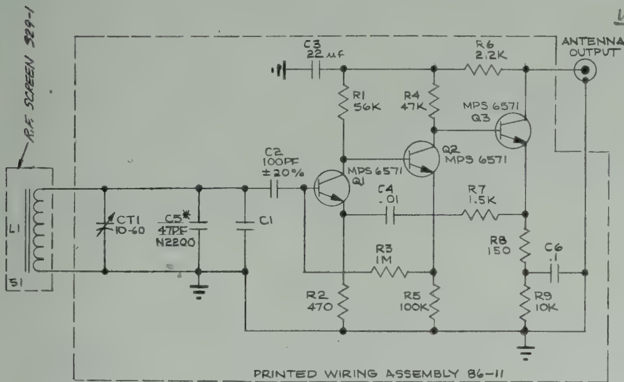
8-17 After re-tuning, if the antenna does not have an output, as above, it should be returned to the factory for repair.

8-18 In some cases it may not be practical to return the antenna. Below is information for performing field repairs.

8-19 After it has been determined by the above tests that the antenna is defective, use a sharp knife and cut open the end plate on the tubing on which the output connector is mounted. The preamp assembly can then be pulled out and repaired with the data and schematic on the following page. After repairs are complete, the end can be resealed with common PVC cement.

RESISTANCE OF OUTPUT TO GROUND
~ 30-100K (DEPENDS ON METER)

VOLTAGE WITH ANTENNA CONNECTED ~ 3-5 VOLTS



SYMBOL	DESCRIPTION	PART #	QTY
C1	Cap. Ceramic Disc. 150pf	26-18A	1
C2	Cap. Monolithic 100pf ±20%	36-33	1
C3	Cap. Tantalum 22uf	32-45	1
C4	Cap. Monolithic .01uf	36-83	1
C5	Cap. Dipped Mica 47pf	29-24	1
C6	Cap. Monolithic .1uf	36-95	1
Q1	Transistor MPS 6571	175-5	3
Q2	Transistor MPS 6571	175-5	3
Q3	Transistor MPS 6571	175-5	3
R1	Resistor Carbon 56K	2-115	1
R2	Resistor Carbon 470	2-65	1
R3	Resistor Carbon 1M	2-145	1
R4	Resistor Carbon 47K	2-113	1
R5	Resistor Carbon 100K	2-121	1
R6	Resistor Carbon 2.2K	2-81	1
R7	Resistor Carbon 1.5K	2-77	1
R8	Resistor Carbon 150	2-53	1
R9	Resistor Carbon 10K	2-97	1
CTI	Cap, Variable 10-60pf	33-60	1
PWB	Printed Wiring Board, Antenna Preamp	85-11	1
	NOTE: FOR A-77.5FS ONLY		
C5	Omit		
C1	Cap. Dipped Mica 68pf	29-29	1

STOPS WORKING WITH SUPPLY < 2 VOLTS

Figure 8-2

NOTE: HAD PROBLEM 12/14/83 WITH VERY LOW OUTPUT [illegible], VOLTAGE WITH ANTENNA WAS ~ +.8V. FOUND RESISTANCE WAS ~ 2K, PROBLEM CAUSED BY WATER [illegible] UNIT CAUSING CORROSION OF OUTPUT CONNECTOR TERMINAL TO GROUND ON PC BOARD. CLEANED, DRYED [illegible]

TRUE TIME
GLENN HARDEN

WWVB TIME CODE

9-1 INTRODUCTION

9-2 The National Bureau of Standards radio station WWVB, located in Fort Collins, Colorado (Latitude 40° 41' 28.3"N, Longitude 105° 02' 39.5"W), transmits a modified IRIG H time code with a power of 13 KW E.R.P.. The modified IRIG H time code is a binary coded decimal (BCD) with a one-minute time frame.

9-3 CODE AND CARRIER

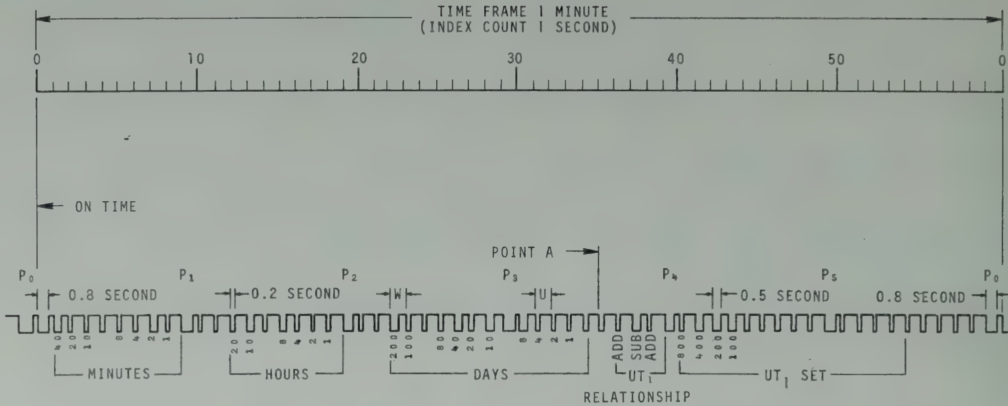
9-4 On July 1, 1965, WWVB began broadcasting time information using a level-shift carrier time code. The code is broadcast continuously and is synchronized with the 60 kHz carrier signal. Beginning in mid 1973 these broadcasts were made on a continuous basis eliminating the periodic Tuesday shutdown.

9-5 MARKER GENERATION

9-6 As shown in the Figure below, the signal consists of 60 markers each minute, with one marker each second. (Time progresses from left to right.) Each marker is generated by reducing the power of the carrier by 10 db at the beginning of the corresponding second and restoring it.

1. 0.2 seconds later for an uncoded marker or binary "zero".
2. 0.5 seconds later for a binary "one".
3. 0.8 seconds later for a 10-second position marker or for a minute reference marker.

Chart depicts 10 db carrier level drops as transmitted.



1 PPM FRAME REFERENCE MARKERS
BINARY CODED DECIMAL TIME-OF-YEAR CODE WORD (23 DIGITS)
CONTROL FUNCTIONS (15 DIGITS) USED FOR UT_1 CORRECTIONS
6 PPM POSITION IDENTIFIER MARKERS AND PULSES (P_0 THRU P_5)
(REDUCED CARRIER 0.8 SECOND DURATION PLUS 0.2 SECOND DURATION PULSE)
W - WEIGHTED CODE DIGIT (CARRIER RESTORED IN 0.5 SECOND - BINARY ONE)
U - UNWEIGHTED CODE DIGIT (CARRIER RESTORED IN 0.2 SECOND - BINARY ZERO)

TIME AT POINT A
258 DAYS
18 HOURS
42 MINUTES
34.3 SECONDS

9-7 MARKER ORDER AND GROUPS

9-8 The 10-second position markers, labeled P0 through P5 on the diagram, occur respectively as the 59th, 9th, 19th, 29th, 39th, and 49th second pulses of each minute. The minute reference marker begins at zero seconds. Uncoded markers occur periodically as the 4th, 14th, 24th, 34th, 44th, 54th seconds pulses and also as the 10th, 11th, 20th, 21st, 35th, 55th, 56th, 57th, and 58th seconds pulses of each minute. Thus every minute contains twelve groups of five markers, each group ending either with a position marker or an uncoded marker.

9-9 INFORMATION SETS

9-10 Each minute the code presents time-of-year information in minutes, hours, day-of-the-year, and the actual milliseconds difference between the time as broadcast and the best known estimate of UT_1. The first two BCD groups in the minute specifies the minute of the hour; the third and fourth BCD groups make up a set which specifies the hour of the day; the fifth, sixth, and seventh groups form a set which specifies the day-of-year. A set made up of the ninth, tenth, and eleventh BCD groups, specifies the number of milliseconds to be added or subtracted from the code time as broadcast in order to obtain UT_1. The relationship of the UT_1 scale to the time as coded is indicated in the eighth group.

9-11 If UT_1 is "slow" with respect to the code time, a binary "one" labeled SUB (subtract) on the preceding Figure, will be broadcast in the eighth group during the 38th second of the minute. If UT_1 is "fast" with respect to the code time a binary "one", labeled ADD, will be broadcast in the eighth group during the 37th and 39th seconds of the minute. The twelfth group is not used to convey information.

9-12 DIGITAL INFORMATION

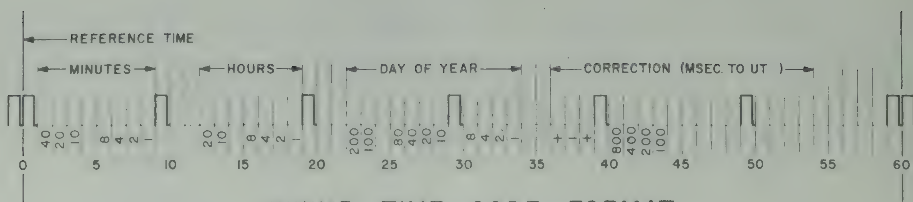
9-13 When used to convey numerical information, the four coded markers used as digits in a BCD group are indexed 8-4-2-1 in that order. Sometimes only the last two or three of the coded markers in a group are needed, as in the first groups in the minutes, hours, and days sets. In these cases, the markers are indexed 2-1, or 4-2-1, accordingly. The indices of the first group in each set which contains two groups are multiplied by 10. Those of the second group of such a set are multiplied by 1. The indices of the first group in each set which contains three groups are multiplied by 100; those of the second group are multiplied by 10, and those of the third group by 1.

9-14 Example: A specific example is indicated in the Figure 9-1. The occurrence of two binary "ones" in the "minutes set" indicates that the minute contemplated is the 40 + 2 = 42nd minute. Similarly, the two binary "ones" in the "hours set" indicate the 10 + 8 = 18th hour of the day, while the four binary "ones" in the "days set" indicate the 200 + 40 + 10 + 8 = 258th day of the year.

9-15 It is seen from the "UTI Relationship" group and the "UTI Set" that one should subtract, from any second in this minute, 400 + 200 + 100 = 700 milliseconds to get an estimate of UTI. For example, the 35th UTI interval would end 700 milliseconds (or 0.7 second) later than the end of the 35th second. In other words, the UTI scale reading for the end of the 35th second would be 18h 42m 34.3s, since 35.0s - 0.7s = 34.3s.

9-16 If more detailed and further information on these broadcasts are required please write to the address on the next page and ask for a copy of the current issue of National Bureau of Standards Publication #432.

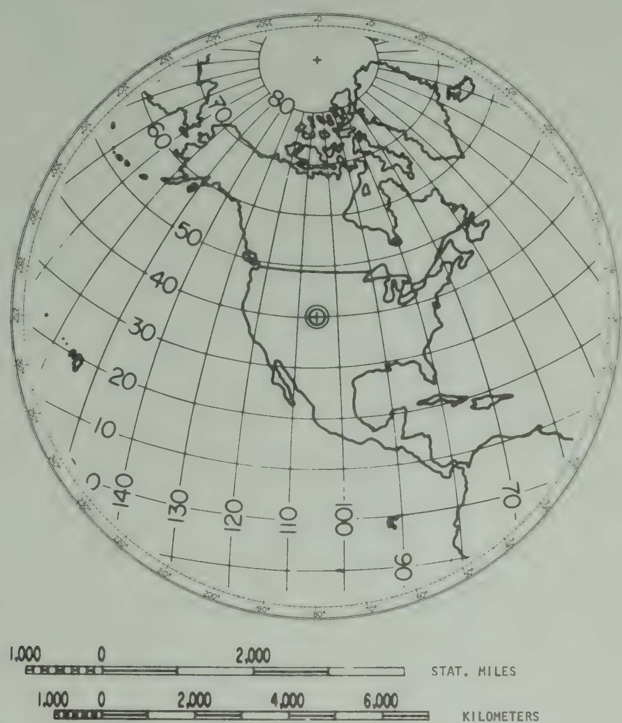
Time and Frequency Division
Institute for Basic Standards
National Bureau of Standards
Boulder, Colorado 80303



WWVB TIME CODE FORMAT

SECTION X

GREAT CIRCLE MAP OF THE NORTHERN PORTION OF THE WESTERN HEMISPHERE CENTERED ON FORT COLLINS, COLORADO



TO DETERMINE THE COMPASS HEADING FOR ANTENNA ORIENTATION FROM YOUR LOCATION TO FORT COLLINS, COLORADO: Draw a straight line from the receiving location through Fort Collins, Colorado point ⊕ on the map and continue until the line intersects the outer ring. The point at which the line intersects the outer ring indicates the compass heading for Fort Collins from you location.

SECTION XI

MEASURED FIELD INTENSITY OF WWVB